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OUTLINE OF THE NEW THEORY OF EARTHQUAKES.*

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FOR POPULAR ASTRONOMY.

Among all the varied natural phenomena witnessed upon our planet nothing so excites the dread and terror of mankind as an earthquake, which is at once violent and so sudden and unexpected as to alarm the calmest mind. That this direful feeling has prevailed in all ages we are amply assured by the comparisons made in the Bible and other venerable works of antiquity, which make known the consternation inspired among the people by these terrible natural commotions. Thus we read in history that some of the Emperors of Rome, especially Trajan and Hadrian, while witnessing the chariot races at Antioch and other places, found it advisable to withdraw from the amphitheatre and retire into the open spaces, in order to avoid the danger of falling walls. And the history of Greece and Rome abounds in stories of the religious anxiety excited among the people by earthquakes, which were believed to be signs of evil omen, sent from the infernal and marine divinities, but especially Poseidon, "the earthshaker," to whom so many temples were dedicated on isthmuses, promontories and other regions in the neighborhood of the sea.

When a great earthquake took place, and was followed by a series of after-shocks, impressively recalling both the terror and the disaster of the principal disturbance, which may have laid waste cities and devastated whole countries, it is not wonderful that the people who had sustained such losses were troubled and wrought up to a high pitch of excitement. In such emergencies the god Poseidon above all others called forth the veneration of the people; and he was generally held to be the most important of the infernal and marine divinities, because he held both the power of earthquakes and of those dreadful inundations by the sea, which were so often noticed

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to accompany violent seismic disturbances in the Peloponnesus and elsewhere.

The wide-spread alarm and religious affliction of the inhabitants of the Peloponnesus after the great Achaian earthquake of 373 B. C. is especially remarked by Diodorus Siculus, and other historians. At the same time it is stated that the natural philosophers explain these phenomena by natural and necessary causes, rather than by the wrath of the gods. But during the ages of Greek Polytheism, and even during the earlier centuries of Christianity, such disasters were always believed by the multitude to be a sign of the divine displeasure. Sometimes they were attributed to the wickedness of an emperor, or to the sins of factional opponents; the heathens charging them upon the Christians and the Christians laying them to the idolatrous conduct of the heathens.

In view of the undeveloped state of science in former times a modern student can easily understand the great perplexity of the ancients, in the midst of such terrible calamities. The Senate of Rome on more than one occasion did what it could to alleviate the sufferings of the people, which were partly real and partly imaginary. We find several accounts of the sending of formal embassies for the offering of public sacrifices to the angry divinities. If these sacrifices did not quiet the agitating forces of nature, they at least calmed the people and thus allayed their imaginary afflictions, and were therefore of service to the state.

It is well known that both the ablest statesmen and generals of antiquity regarded earthquakes as proceeding from natural causes; and I have recently been at some pains to translate the theories held by Aristotle and other leading Greek philosophers. Aristotle gives the views of those who preceded him, and his own theory was generally adopted by his successors. We may infer this by the way in which it was followed by such writers as Strabo and Pliny.

Aristotle placed his discussion of earthquakes in the book on *Meteorology*, because he ascribed the shaking of the Earth to vapor confined within the crust, and agitating to effect an escape so as to diffuse itself in the atmosphere. He recognized the high internal temperature of the Earth from the warm springs observed to break forth in many places, and from the eruptions of volcanoes which he had witnessed in the Aeolian Islands and elsewhere. Both he and Strabo mention eruptions occurring in the bed of the sea, and they also notice the great

seismic sea waves which frequently accompany violent earthquakes originating near the sea shores.

Aristotle and Pliny distinctly remark that earthquakes are especially prevalent in maritime districts; and they attribute this phenomenon to submarine passages, conceived as deep conduits, by which air and water obtain access to the heated matter in the bowels of the Earth. They held that earthquakes are due to the agitation of imprisoned vapors even when none of it escapes to the surface, but all remains hidden beneath the Earth's crust. That the cause is the same when a volcanic outbreak occurs and when only an earthquake takes place without eruption, Aristotle affirmed on the ground of the similarity of the movement in the two cases.

To an unbiased naturalist like Aristotle it did not seem strange that in the one case the vapor should break through and diffuse itself in the atmosphere, while in the other it continued to agitate till movements occurred which gave more space beneath the Earth's crust, and was then followed by a cessation of the shocks. Aristotle's view was thus consistent with Newton's rule of philosophy, that the same effects are to be ascribed so far as possible to the same causes; and in marked contrast with the modern method of dividing earthquakes into two arbitrary classes, volcanic and tectonic, according as they are accompanied by eruption, or only by a surface's dislocation of the Earth's crust along a fault line.

While Aristotle's theory is imperfect in many respects, the general ideas underlying it are essentially sound, and in reading this work written more than twenty-two centuries ago, one cannot but be impressed both by his penetration into the nature of things, and by the vast extent of his knowledge. With characteristic independence he refused to accept the views of his predecessors, but examined *de novo* all questions upon their merits, so far as the existing state of science would permit. He is thus led to many interesting remarks, and the criticisms which he offers are often as good as can be made today.

In view of the great afflictions due to earthquakes suffered by so many countries from the earliest ages, it seems to the modern student truly remarkable that our understanding of the cause of these disturbances has remained so unsatisfactory. Whether we read in Strabo or Pliny that a great earthquake in Syria had laid waste twelve cities in a single night, or turn to the current books and press dispatches, which tell of widespread devastation by modern earthquakes, we are left

equally in the dark as to the cause of these calamities. In current discussions we often see it stated that earthquakes may occur anywhere, and that no place is free from the dreadful ravages which they inflict upon large portions of mankind. This statement obviously is not correct, yet it shows that heretofore science has not reached the true laws of these phenomena.

The main object of science is the illumination of the human mind, and much of it scarcely admits of application to practical affairs, so as to alleviate human suffering; but if we had a true science of earthquakes it ought to be indeed of the highest humane as well as scientific interest. Shall our cities continue to be devasted and rebuilt without an understanding of the disturbing cause? If so what advance has our boasted civilization made over that of the Greeks and Romans? Nay, shall we not know even the regions especially afflicted by earthquakes? We could indeed have learned this from the study of Aristotle; but in our time we claim, though not always justly, to have improved on the knowledge of the ancients. If we do not find out the regions especially subject to earthquakes, so as to forewarn the people as to what kind of houses to build, and how to protect their cities from fire in the case of an earthquake, of what practical use is science to the community? Some branches of science might be very excellent indeed and still be of no use to the multitude of people; yet this obviously is not true of a science which deals with earthquakes imperiling the lives and property of thousands of our fellow citizens.

We must confess that heretofore this knowledge of the cause of earthquakes has not been forthcoming. But as a physicist believing in the existence of natural laws, which, if known, would be of the greatest service to mankind both now and throughout coming ages, I am going to treat of earthquakes and kindred phenomenon connected with the physics of the Earth. The theory of which I shall treat has been recently presented to the American Philosophical Society in Philadelphia, and I take this occasion to acknowledge my indebtedness to this illustrious society for the publication of lengthy arguments which can be mentioned here only with the utmost brevity.*

* 1. The Cause of Earthquakes, Mountain Formation and Kindred Phenomena connected with the Physics of the Earth. Proc. Am. Philos. Society, 1906, issued March, 1907.

2. On the Temperature, Secular Cooling and Contraction of the Earth

At the time of the great earthquake at San Francisco, I had just finished the researches on the Physical Constitution of the heavenly bodies which have been recently published in the *Astronomische Nachrichten*; and as the explanations of the earthquake then made public by men of science did not seem to me to be well founded, I temporarily laid aside astronomical work in order to take up this problem of the Physics of the Earth. It is not too much to say that the papers which the American Philosophical Society did me the honor to publish have awakened a lively interest in the scientific world; and while one can scarcely hope that every difficulty has been overcome, it is evident that at least a good foundation has been laid for the true theory of earthquakes, mountain formation and kindred phenomena connected with the physics of the globe.

Since the processes involved in earthquakes are forever hidden from mortal view, the discovery of the cause involved naturally has been very difficult. But as the effects would become most sensible in earthquakes of the world-shaking class, it was felt at the outset that the investigation should be restricted to the study of these great phenomena. If the study of the greatest earthquakes enabled us to reach the underlying cause, the inquiry could later be made to include the smaller disturbances, many of which are after-shocks of the great earthquakes.

In speaking of earthquakes therefore we shall have in mind primarily earthquakes of the world-shaking class. If we had attempted to study all earthquakes together, the results could only have been hopeless confusion; for we should have been unable to discover the processes even of the greatest earthquakes.

One of the most remarkable results of these inquiries is the conclusion that the Earth is not shrinking, as commonly held in all the physical sciences for the past 80 years; but that it may indeed be slightly expanding. Another is that there is a progressive secular desiccation of the oceans, which are becoming narrower and also deeper in many places, so that as the world grows older the intensity of the earthquakes is slowly increasing, not diminishing. But obviously there has been no sensible change within the historical period.

and on the Theory of Earthquakes held by the Ancients. Proc. Am. Philos. Society, 1907.

3. The New Theory of Earthquakes and Mountain Formation as illustrated by Processes now at work in the Depths of the Sea. Proc. Am. Philos. Society, 1907, issued in March 1908.

We shall now proceed to state the cause of earthquakes and related phenomena, and after so doing shall resume the consideration of the other questions connected with the physics of the globe.

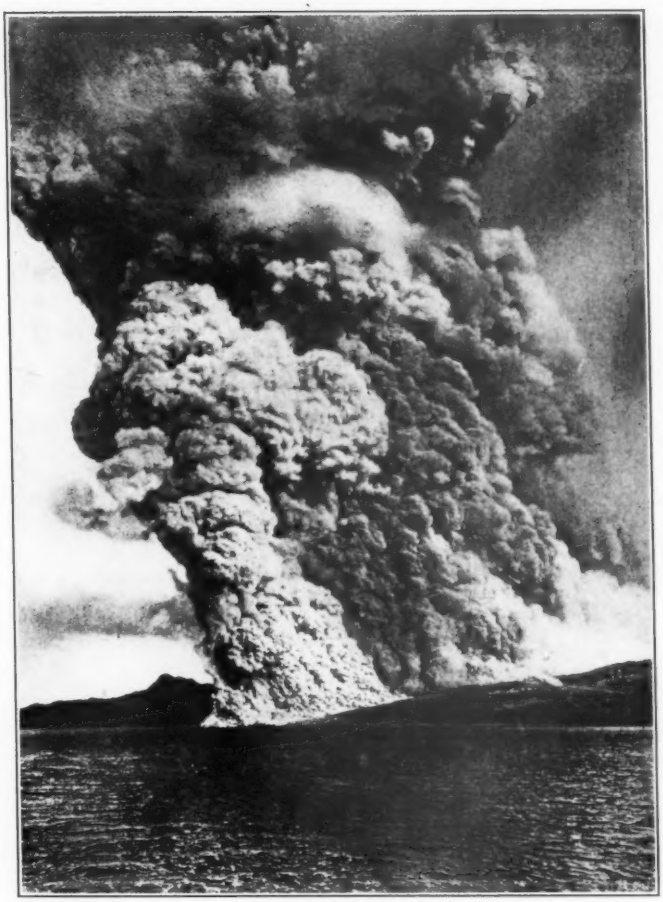
1. It is shown that the principal cause of world-shaking earthquakes is the secular leakage of the ocean bottoms, which produces steam beneath the Earth's crust. When the pressure has sufficiently accumulated the movement of the underlying molten rock shakes the Earth, lays waste cities and devastes whole countries. Much steam is formed under the ocean, but scarcely any under the land, and hence the usual process of movement consists in the expulsion of lava from beneath the sea, and the pushing of it under the land. The crust is thus pushed up and broken along the seashore, and thus forms mountains parallel to the coast.

2. The mountain systems of the world have been formed by this expulsion of lava from under the sea, and not at all by the shrinkage of the globe. Taking account of the mere lay of the mountains relatively to the sea, it is proved by the theory of probability that the chances are at least a decillion decillions to one that they were formed so exactly parallel to the coast by a true physical cause depending on the oceans. Moreover there are other phenomena to be considered of such weight that it becomes an absolute certainty that the mountains are formed by the sea.

3. The coast frequently is noticed to be upheaved during earthquakes, and the adjacent sea bottom is shown to sink, from the way in which the water retires before the inrush of the accompanying seismic sea wave. The sea does not withdraw from the land by the violence of the agitation of the ground during the earthquake, but slowly drains off afterwards, as in the ebbing of a tide, only the withdrawal is more rapid in the case of the movement before the sea wave; and as the sea level near the shore is thus lowered sometimes by forty or fifty feet, so that vessels at anchor in seven fathoms of water are left resting on the ground, it follows that the sea bottom sinks some distance from the shore, and the water rushes in from all sides to fill up the depression. When the currents meet at the center the water is forced up into a corresponding elevation, above the normal sea level, and the collapse of this aqueous ridge sends a great wave ashore, to add to the horror of the earthquake.

4. If then the sea bottom frequently sinks and the coast is

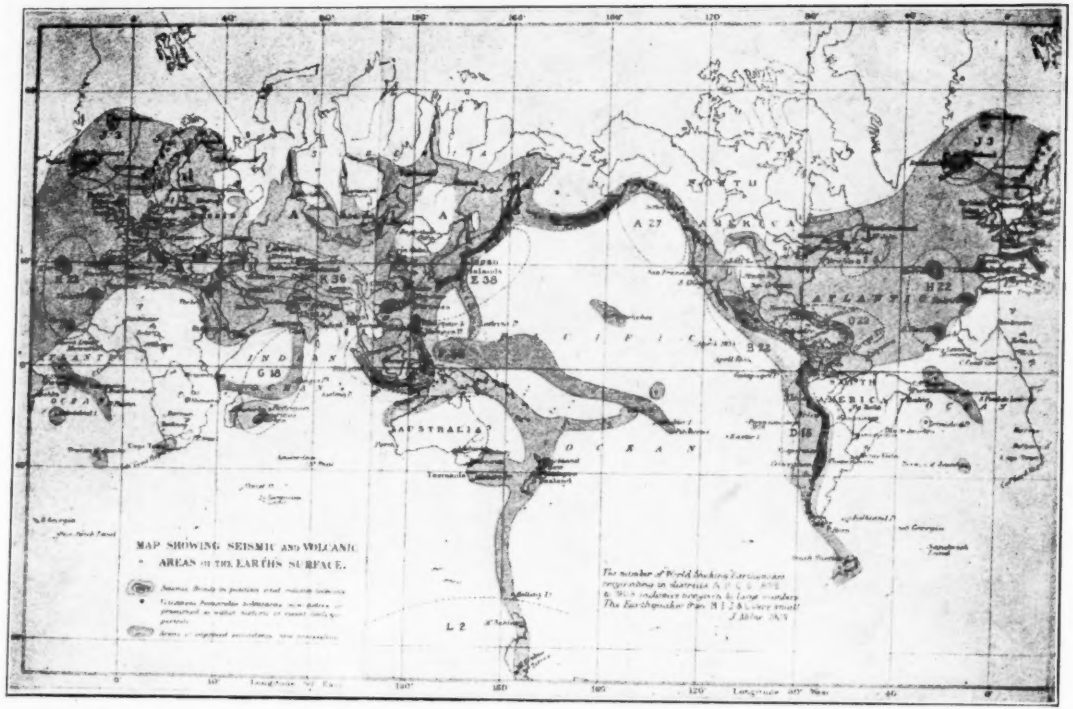
PLATE VII.



MOUNT PELÉE.

The Burning Cloud of December 6, 1902, seen from the sea.

PLATE VIII.


MAP SHOWING SEISMIC AND VOLCANIC
AREAS OF THE EARTH'S SURFACE.

simultaneously upraised, it follows that lava is expelled from under the sea and pushed under the land. For in the regular order of nature the sea bottom could not sink unless it was in some way undermined, and the coast could not be uplifted unless something was pushed under it, and as one sinks while the other rises it follows that lava is expelled from under the sea and pushed under the land. Not only is this process now going on along the west coast of South America, and elsewhere, as repeatedly observed within historical times, but we may also affirm that the long continuation of this undermining in the past has sunk the sea bottom down into a deep trough and at the same time pushed such vast quantities of lava under the adjacent mountains that the lofty peaks in the Andes with snow-capped summits now seem to near the stars. There is thus direct continuity between the small movements observed within the historical period and the vastly greater effect of these forces operating over immense periods of time.

5. The process by which mountains and deep ocean troughs are formed is even better illustrated in the Aleutian and Kurile Islands, where the mountains under water are just rising out of the sea and the adjacent ocean trench is very narrow, and runs exactly parallel to them for great distances (see Manual of Tides, Coast Survey Reports, 1900, Part IV, A, by Rollin A. Harris, including maps of the depths of the ocean). This chain is also one of the worst earthquake belts in the world, and many of the mountains have burst open and become volcanoes. The earthquakes are frequently accompanied by great seismic sea waves, showing that the bed of the ocean sinks after lava has been expelled from under it in the formation of mountains. If the process thus made out is a true law of nature it follows that all the great mountain chains of the globe were formed by this same process, though in some cases the recession of the sea coast due to the movement of the crust by earthquakes, has changed the original shapes of the troughs, and consequently can now be make out only by careful investigation.

6. Our present knowledge of the Earth's surface does not enable us to decide just what movement of the land has taken place in each case, but the parallelism of the mountains to the sea coast is sufficiently remarkable to attract universal attention. Heretofore the cause of this phenomenon has been quite obscure, and some have inferred that it is a "coincidence which is only in part causal." It is shown, however, as already

remarked, that the chances are at least a decillion decillions to one that the parallelism depends on a true physical cause connected with the sea. It is absolutely unthinkable that the Pacific ocean could be so effectively walled in by great mountain chains all around, unless the mountains were formed about the ocean itself, by the expulsion of lava, in the way we have described.

7. In 1899, September 3-20, a terrible earthquake took place at Yakutat Bay, Alaska, during which the coast was elevated for more than a hundred miles, and at the maximum the elevation amounted to 47⅓ feet. Elevations of from 7 to 20 feet were common, while small depressions also occurred in a few places. This case was carefully investigated by Professor R. S. Tarr of Cornell University and Mr. Lawrence Martin of the National Geographical Society; and their memoir in the Bulletin of the Geological Society of America, Vol. 17, May, 1906, is illustrated by photographs of the most convincing kind, showing the uplifted coasts, with barnacles still adhering to the rocks. Their investigation is classic and absolutely conclusive. In the confused state of scientific opinion heretofore prevailing geologists could deny the bodily uplift of the solid land; but after the publication of this memoir they could no longer legitimately maintain this attitude. And if one instance of elevation by a powerful earthquake could be clearly established, it naturally followed that others could arise from similar causes. Last year the earthquake at Valparaiso, August 16, 1906, is said to have raised the Chilian coast about ten feet; and many similar movements at other places both in ancient and modern times can be certainly established.

8. The fact that no active volcano exists over about 100 miles from the sea or other large body of water, and the further fact that according to Geikie 999 in 1000 parts of the escaping vapor is steam, shows the dependence of volcanoes on the sea. The activity of 105 volcanoes in the Andes within historical time shows that volcanoes are nothing but ordinary mountains broken through by the pressure of subterranean steam. Hence it follows that the same forces which raise the mountain chains and peaks also cause the eruption of some of them.

9. The vapor of steam and no other is the cause of both mountain building and of volcanic outbreaks; for mountain building always takes place in or near the sea, and volcanoes

throughout the world develop near the center of the earthquake belts. Volcanoes emit chiefly vapor of steam, and eruptions generally cease when the vapor has escaped into the atmosphere. Thus earthquakes, volcanoes, mountain formation, and seismic sea waves are all due to a common cause.

10. As the expulsion of lava from under the sea causes the earthquakes and seismic sea waves, it follows also that all mountains are underlaid with pumice of various degrees of density, which is simply molten rock inflated with steam and then cooled and dried. The expulsion of such vast quantities of pumice from volcanoes shows that there must be a process for its abundant manufacture in nature, and that it must have been formed under all mountains when they were originally upheaved. The prevalence of pumice in volcanic regions is therefore accounted for in a perfectly simple manner. The grinding up of pumice makes volcanic ashes, and hence arise the vast quantities of this dust blown out of many volcanoes. Pumice and its disintegrated product in the form of ashes, result from the diminished pressure exerted on steam-saturated lava, when it is pushed under the mountains where the crust is broken, and increased expansion of the molten rock takes place.

11. The formation of islands in the sea and of plateaus on land, is to be explained by elevation of a portion of the Earth's crust by the injection of lava beneath. This lava comes from neighboring areas, which are thus undermined, unless the partial cavity is again filled up by an additional supply of molten rock. Hence plateaus such as those of Titicaca and Tibet are closely associated with the expulsion of lava, which originally caused the uplift of the Andes and Himalayas. In many cases islands in the sea have depressions near them, showing that the sea bottom was undermined in the elevation of the islands, and afterwards sank down to secure stability.

12. As all mountains and plateaus exhibit a feeble attraction when measured in geodetic operations, it follows that the cause of this phenomenon is the pumice underlying these elevated portions of the crust, which makes them attract as if they were hollow, or filled with caverns. This was noted by Bouguer and LaCandamine in their observations on Chimborazo as early as 1738.

13. When the subterranean pressure becomes great enough to shake the Earth's crust, it naturally moves at the nearest

fault line, where the rocks are broken, and the resistance is least *but the movement observed is the result, not the cause of the earthquake.* It has been customary heretofore to explain earthquakes by the movement of faults, without assigning the cause of the fault movement, or by vague references to the supposed secular cooling of the Earth. Such procedure is altogether illogical, for it does not account for the origin of faults, nor even point out the correct cause of their movement.

14. If faults were due to the secular cooling of the Earth they ought to originate and move in the interior of continents as well as along the ocean shores; for acre for acre as much heat is being lost by Kansas, or Sahara, as by any sea coast or ocean bed in the world. Yet no important movements occur inland, while the sea coast is repeatedly shaken. The constant shaking of the Andes compared to the general quiescence of the Rocky mountains shows the effect of proximity to the sea, and proves that the secular cooling of the Earth is not a true cause of earthquake movements.

15. In the papers published by the American Philosophical Society at Philadelphia it is shown that the effects of secular cooling are wholly inappreciable, and that the Earth is not really contracting; but in all probability slightly expanding, owing to the predominant effects of elevations of the land by world-shaking earthquakes, 120,000 of which have occurred since the beginning of the Christian Era. And it is calculated that the effects of elevation may exceed the effects of contraction from 10 to 100 times, so that in all probability the globe is really expanding.

16. It turns out therefore that the doctrine of mountain formation based on the theory of contraction and now held for some 80 years is quite devoid of real foundation. If the Earth is not shrinking another cause must be sought to account for the observed elevations of the crust as seen in mountain folds; and it should explain mountain ranges in the sea as well as on the land. The present theory meets this severe test perfectly, and is beautifully illustrated by the phenomena exhibited near the Aleutian and Kurile Islands. Here the earthquakes are raising islands and at the same time sinking down the adjacent sea bottom, as may be confidently inferred from the accompanying seismic sea waves. These long narrow trenches have been dug out by the expulsion process, and it is still going on at the present time. No other interpretation of the observed phenomena is really possible.

PLATE IX.

a. Mountain formation just beginning.

b. Mountain formation in the middle stages.

c. Mountain formation in the later stages.

d. New range rising from the sea.

17. The whole Plateau west of the Rocky Mountains has been raised from the sea in recent geological time. This is shown by the abundant beds of fossils, and by the numerous parallel mountain ranges nearer the Pacific Coast. The San Joaquin and Sacramento Valleys have been recently raised from the sea, and the great earthquake at San Francisco, April 18, 1906, was but one of an infinite number which have raised the coast range little by little and finally lifted California above the ocean level. Earthquakes obviously will recur in California, but no important disturbance is to be expected at San Francisco for at least a generation. This is inferred from the study of other places similarly disturbed during the historical period, and from the nature of the process of ocean leakage, which is very slow and gradual.

18. The cause of the terrible earthquakes in Japan is now perfectly clear, namely the leakage of the deep sea just to the East of Nipon, known as the Tuscarora Deep. By the expulsion of lava from under this area the whole island of Nipon has been lifted above the sea, and the process still continues with increasing violence. The east coast of Japan has risen considerably within the historical period, and naturally a movement of this kind confirms the theory here developed.

19. The present theory of mountain formation enables us to account for all the principal mountain ranges of the globe, and the more gradual slopes which they exhibit towards the sea from which the lava has been expelled in the process of elevation. In the case of islands the mountains run lengthwise, right through their centers like veritable backbones. In other cases lava escapes under larger submarine areas which will eventually be raised above the sea and formed into larger islands or continents. The principal cause of the movement of the Earth's crust is everywhere the same, but we do not yet know the details of all parts of the globe, because most of it is under water, and even that above sea level is very imperfectly surveyed.

20. As land is raised above the sea by earthquakes, it follows that the chief effect of seismic activity is the formation of more land. Since this narrows the oceans, and water is also constantly sinking down into the Earth, and only a small part of it again escapes through the vents of volcanoes, it follows that there is a secular desiccation of the oceans, but the process is excessively slow, and not certainly recognizable within the historical period. Yet a portion of the lowering

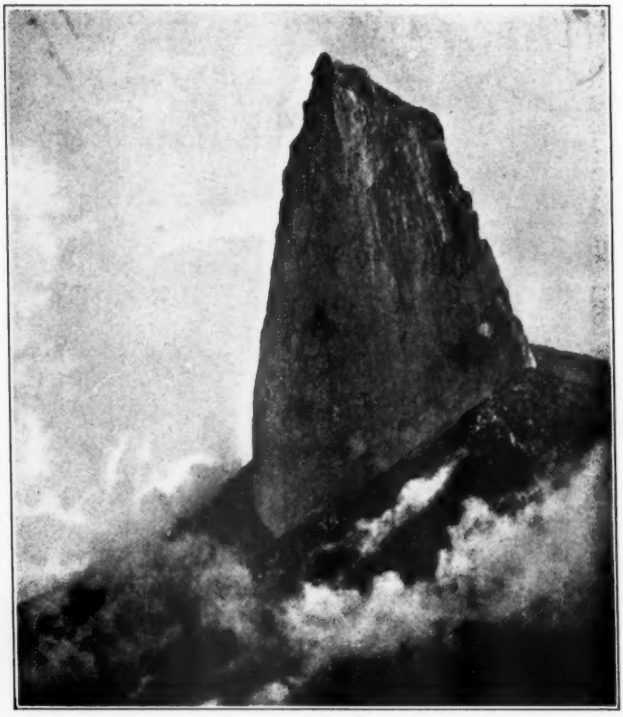
of the strand line noticed in later geological ages may be due to this cause.

21. In studying the sinking of the sea bottoms in connection with the expulsion of lava for the elevation of coasts and the formation of mountains, the writer took up the problem of the sinking of the Homeric City of Helike, after the great earthquake in Achaia, in 373 B. C., which occurred during the lifetime of Aristotle and Plato. And it was possible to prove from historical authorities that the subsidence amounted to about 100 feet, which shows that after that earthquake had pushed lava under the mountains in Arcadia, the bed of the Gulf of Corinth gave down, and carried the shore on which Helike stood down with it, so that, as Pausanias says, only the tops of the trees about the temple of Poseidon remained above the water. This famous disaster, which happened when Plato was 54 and thus at the head of the Academy in Athens, and Aristotle was a boy eleven years old, was therefore due to the expulsion of lava from under the Gulf of Corinth. Is it not remarkable that after the lapse of so many centuries we should be able to explain by simple principles a calamity which so disturbed the Greek world, and completely bewildered even the wisest of the Athenian sages?

22. As the result of his researches Aristotle held that earthquakes are due to vapors in the Earth, seeking to escape and diffuse themselves in the atmosphere. This view was generally adopted by the ancients, for we find it clearly stated by Strabo and Pliny, who studied the writings of Aristotle. Strabo also holds the theory that the land is uplifted and depressed by earthquakes. He seems to have held that not only islands and continents but also mountains are thus produced, which essentially accords with the theory of Aristotle, who had carefully studied volcanic and earthquake phenomena, including several eruptions observed to occur in the sea. Aristotle had observed that maritime districts are especially subject to earthquakes. In view of the results of modern observations and the theory now established, may we not justly consider this to be one of the most remarkable inductions of antiquity?

23. The theory now developed was therefore vaguely outlined by the leading Greek philosophers, especially by Aristotle, who associated the causes producing earthquakes and volcanoes, islands and seismic sea waves, all of which were attributed to the accumulation of vapors in the Earth. This natural order of thought as developed by the Greeks presents a strik-

PLATE X.



THE SHATTERED OBELISK OF MOUNT PELÉE.

Photographed by Professor Angelo Heilprin.

ing contrast to the disconnected and anachronous views on these subjects still current in our own time, and admonishes us to give ample heed to the independent conceptions of the Greeks who were not so much swayed as some moderns are by contemporary opinion.

24. The theory recently current that great seismic disturbances of the Earth's crust are due to unequal loading of different areas arising in erosion, denundation and deposits of sediment is, to say the least, unworthy of modern science, because such forces could produce no uplifts whatever, nor could they produce any serious continuous shaking, even if a slight movement of the ground should occur. It is the movement of molten rock under the Earth's crust, in the process of adjustment of steam pressure, which forms mountains, shakes down cities and lays waste whole countries. The development of the highest mountain ranges about the deepest oceans shows that these great uplifts of the crust depend upon the sea and not at all on the shrinkage of the globe. The indications of nature indeed are as clear as the noon-day Sun, and all we have to do is to apply to these phenomena a little of the saving common sense which has distinguished mankind in the better ages of the human mind.

This summary of the results of these researches is necessarily incomplete, but probably sufficiently extended to afford an idea of the trend of the investigation. Among American geologists Dana approached most nearly to the true views of the physics of the Earth's crust, and we shall therefore quote his statements as they were made over forty years ago. Some of his intuitions are quite remarkable.

VIEWS OF DANA.

In the first edition of his *Manual of Geology*, 1863, J. D. Dana treats of the general Features of the Earth and shows how the continents are walled in by mountains, erected about their borders, and finally adds (p. 29):

(a) "The continents thus exemplify the law laid down, and not merely as to high borders around a depressed interior, a principle stated by many geographers,—but also as to the highest border being on the side of the greatest ocean (first announced in American Jour. Sci. (2) xvii, vols. iii, iv, 1847, and xxii, 335, 1856). The continents then are all built on one model, and in their structure and origin have a relation to the oceans that is of fundamental importance." He also observes that the borders of continents are from

500 to 1000 miles wide, and infers that "a continent can not be less than a thousand miles, (twice five hundred), in width," otherwise it would not have the characteristic basin form with mountain barriers about a low interior.

(b) On page 731 he discusses the evolution of the Earth's great outline reliefs, and of the successive phases in its progress, summarizing his conclusions as follows:

I. "The continents have mountains along their borders, while the interior is relatively low; and these border mountain chains often consist of two or three ranges elevated at different epochs."

II. "The highest mountain-border faces the largest ocean, and conversely."

III. "The continents have their volcanoes mainly on their borders, the interior being almost wholly without them, although they were largely covered with salt water from the Azoic age to the Tertiary. Also metamorphic rocks later than the Azoic are most prevalent near the borders."

IV. "Nearly all of the volcanoes of a continent are on the border which faces the largest ocean."

V. "The strata of the continental borders are for the most part plicated on a grand scale, while those of the interior are relatively but little disturbed."

VI. "The successive changes of level on coasts, even from the Azoic age to the Tertiary, have been in general parallel to the border mountain chains; as those of the eastern United States, parallel to the Appalachians, and those of the Pacific side, as far as now appears, parallel to the Rocky Mountains."

VIII. "The continents and oceans had their general outline or form defined in earliest time. This has been proved with regard to North America from the position and distribution of the first beds of the Lower Silurian,—those of the Potsdam epoch. The facts indicate that the continent of North America had its surface near tide-level, part above and part below it (p. 196), and this will probably be proved to be the conditions in primordial time of the other continents also. And, if the outlines of the continents were marked out, it follows that the outlines of the oceans were no less so."

The three other conclusions announced by Dana are of less interest, and need not be quoted here.

(c) The following deductions (p. 732) regarding the positions of the reliefs are of high interest:

"1. The situation of the great mountain chains, mainly near

the borders of the continents, does not indicate whether the elevating pressure acted within the continental or oceanic part of the Earth's crust. But the occurrence between the principal range and the sea coast of the larger part of the volcanoes (and, therefore, of the profound and widely-opened fractures) of these borders, of the most extensive metamorphic areas, and of the closest and most numerous plications of the strata, as so well shown in North America, are sufficient evidence that the force acted most strongly from the oceanic direction."

"2. The relation between the extent of the oceans and the height and volcanic action, etc., of their borders proves that the amount of force in action has some relation to the size and depth of the oceanic basin. The Pacific exhibits its greatness in the lofty mountains and volcanoes which begirt it."

"3. In such a movement, elevation in one part supposes necessarily subsidence in another; and, while the continental was the part of the crust which was elevated, the oceanic was the subsiding part."

In connection with the theory that the mountains are formed by the expulsion of lava from under the sea, through the operation of world-shaking earthquakes, these early views of Dana are of great interest. But in other respects he was led astray by the doctrine of the secular refrigeration of the globe; for he says that "no other cause presents itself that can comprehend in its action the whole globe and all time". He thus speaks as if the entire globe were shrinking, whereas local changes only are occurring, and these always near the sea. Dana's views that "the pressure of the subsiding oceanic portion has acted against the resisting mass of the continents; and thus the border between them has become elevated, plicated, metamorphosed and embossed with volcanoes," is alike misleading and unjustifiable. To produce such an effect the settling of the ocean basin would have to be many miles, and we have shown that no such shrinkage has taken place since the crust was formed; on the contrary there is reason to think that the Earth is expanding at a rate of from 10 to 100 times that of the contraction due to secular cooling. Moreover we have no more right to assume that the continent is squeezed by the settlement of the ocean, than that the ocean is squeezed by the settling of the continent.

(d) We have, however, recalled these views in order to do justice to the most original of the older American geologists, and also to let the student see where he departs from the true

line of thought. Many years ago Rev. O. Fisher showed that shrinkage was wholly inadequate to account for the height of the mountains observed upon the Earth, which are hundreds of times higher than the contraction theory will explain. In the paper on the cause of earthquakes it is shown that the contraction theory is also emphatically contradicted by the present distribution of mountains. And in the second paper, "On the Temperature, Secular Cooling and Contraction of the Earth, and on the Theory of Earthquakes held by the Ancients," it is shown that at present the Earth is not contracting at all; so we are compelled to abandon the older theories entirely.

As heretofore developed geology has presented the strange anomaly of offering no theories adequate to account for the uplift of mountains or the deposits of fossil beds thousands of feet above the sea. This is the more remarkable, since in the days of Humboldt, Lyell, and Darwin, the bodily elevation of the land was an accepted item of belief. But subsequently Lord Kelvin, Sir George Darwin and other eminent British physicists, showed from the investigation of tidal and other phenomena that the Earth as a whole behaved as a solid, and under the influence of this line of thought geologists gave up the doctrine of the bodily elevation of the land, and restricted themselves to the collapse of portions of the crust under gravity. Such a line of thought, however, utterly fails to explain mountains and plateaus and islands, as well as shells and other organic remains at great height above the sea level. But it was felt that the argument of the physicists against the bodily yielding of the Earth was unanswerable, and so it was, but this does not exclude the existence of a layer just beneath the crust which in earthquakes behaves as fluid.

In my researches a theory is developed by which these two views may be reconciled, and it is, I think, clearly proved that in earthquakes there is movement of molten rock beneath the crust. It is this movement of molten rock beneath the Earth's crust which produces most of the dislocations, crumpling, folding, and other phenomena studied in geology. If such a view is justifiable, it shows us how cautious we must be in drawing final conclusions, and how incomplete all the sciences still are today.

We must now refer to Daubrée's experiments, and the problem of explaining how the water gets beneath the Earth's crust, to develop the steam power operative in earthquakes. Daubrée's experiments have shown that under pressure of

PLATE XI.

its own superincumbent column water may pass through cold and enter hot rocks, by capillary action, and increase the pressure within, notwithstanding the increase of steam pressure on the under side. In this way Daubrée explained volcanic eruptions, by which a column of molten lava is forced up into the vent of a volcano. Though Daubrée's results appear to have a good experimental basis, we may prove our fundamental proposition regarding the leakage of the oceans quite independently of these experiments.

Earthquakes are the processes by which mountains are produced, and observation shows that these forces act at a depth of some fifteen miles, where the pressure is so great that no vacancies exist. When the coast is upheaved by an earthquake it is clear that no real cavity is allowed to form beneath; in the same way we may conclude that when the sea bottom sinks after an earthquake no condensation of the matter of average density takes place beneath the bed of the sea. But matter is expelled from beneath the sea bottom and pushed under the land, so that the coast is upraised and the sea bottom sinks to fill up the partial cavity formed beneath the sea by the expulsion of lava.

These phenomena are repeatedly observed in South America, the Aleutian Islands and elsewhere, and, so far as one can see admit of but one interpretation. Hence we may conclude with certainty that the Andes have been formed by the expulsion of lava from beneath the bed of the adjacent ocean; this is the true meaning of the thundering of the earthquakes under the margin of the sea already witnessed for centuries, but not heretofore understood by men of science. This subterranean thunder is the outward expression of the mighty explosive forces by which the crust along the coast is uplifted into some of the mightiest mountains of the globe.

Since the Earth is not contracting, nor experiencing any sensible changes due to secular cooling, it is evident that this expulsion of lava can only be accomplished by explosive vapor such as is seen to issue from neighboring volcanoes, which often break out into eruption simultaneously with an earthquake noticed to produce an elevation of the coast and a sinking of the sea bottom. This vapor therefore is nothing else than common steam.

Now the steam developing beneath the Earth's crust and producing earthquakes and volcanic activity can be traced to but two possible sources: First, the original magma of the

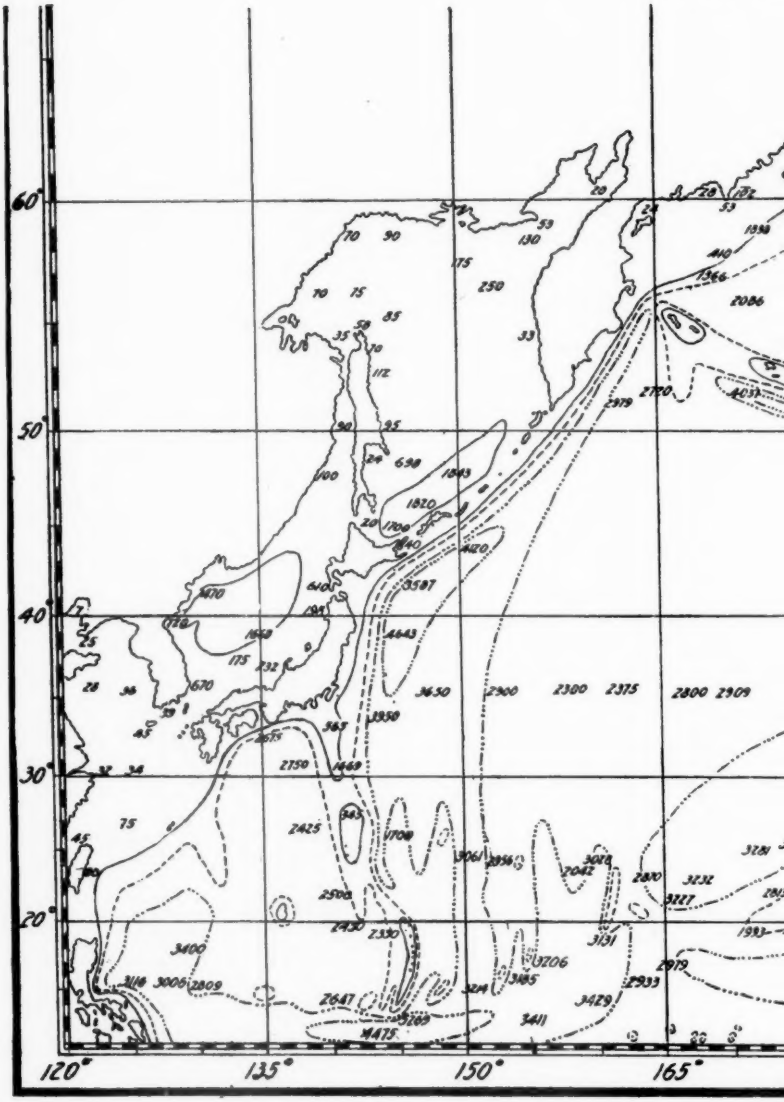
globe, which, in default of a better explanation, has been frequently invoked by the geologist; Second, the secular leakage of the ocean bottoms, effected through fifteen miles of solid rock like granite, which naturally appeals to the physicist. If the escaping steam, or any sensible part of it, came from the central magma of the globe, volcanoes and earthquakes necessarily would occur in the interior of the continents as well as along the coasts, on islands, and in the depths of the sea. For the continents are large areas, and altogether cover more than one fourth of the total surface of the globe; yet the volcanoes and world-shaking earthquakes are confined to the neighborhood of the oceans or other large bodies of water.

It clearly follows therefore that the agitating vapor does not come from the central magma of the globe, but must come from the secular leakage of the ocean bottoms. This is unmistakably indicated by the most overwhelming evidence of nature, and hence it follows that the secular leakage of the ocean bottoms through fifteen miles of rock like granite is effected by the constant pressure of the water upon the bed of the sea. When we recall that the column of water resting on the sea bottom is often five miles deep, giving a steady pressure theoretically adequate for throwing a jet to that height, it is not at all surprising that the water should work down through fifteen miles of rock like granite.

Accordingly it follows also that Daubrée's experiments are applicable to layers of rock from fifteen to twenty miles thick, and our fundamental proposition regarding the secular leakage of the ocean bottoms is proved quite independently of Daubrée's experiments.

In the case of our thinly encrusted planet so largely covered with water, the natural arrangement between the overlying oceans and the underlying molten globe constitutes a laboratory of the most imposing magnitude, infinitely transcending anything ever conceived by man, with gigantic experiments constantly going on. All that is needed therefore is for the philosopher to interpret nature's stupendous operations, which unfortunately only too often prove disastrous to human life, owing to our ignorance and disregard of natural laws. The highest duty of the philosopher is to discover these laws and make them available to the public, so as to contribute as much as possible to the safety and repose of mankind.

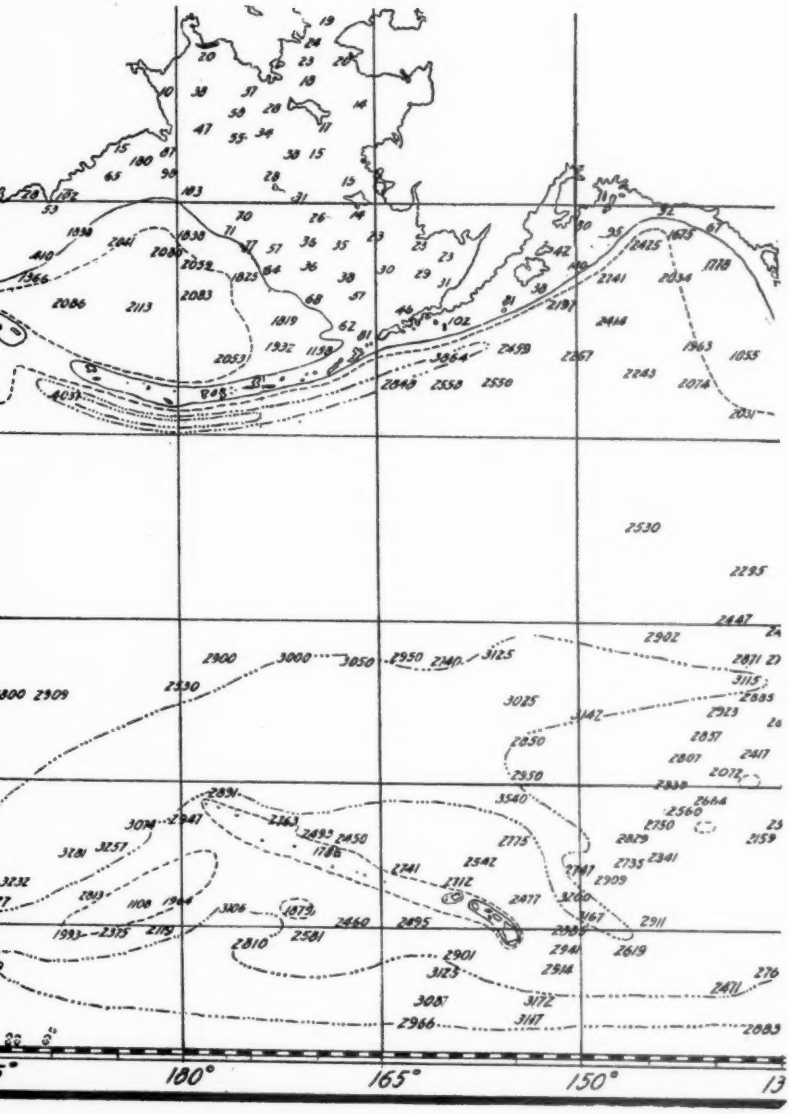
It is often imagined by many that the captains of industry are the principal creators of national wealth and prosperity,



COAST SURVEY MAP OF THE N

4 dots in the contour lines denotes a depth of 4,000 fathoms; 3

LATE XII.



OF THE NORTH PACIFIC OCEAN.

fathoms; 3 dots, 3,000 fathoms; continuous dashes, 2,000 fathoms.

and that discoveries of natural laws are of little value compared to material things. Is it necessary to point out the inadequacy of this view? Is not he who discovers how to safeguard and preserve the property of the state as essential to the public well-being as he who merely develops, without knowing how to build so as to preserve, the products of human labor? Would it be extreme to hold that a real discoverer, a true philosopher, is as valuable to the state as any Captain of industry? His worldly possessions, it is true, may be small, but his discoveries are useful to all mankind of the present and future generations; nay they are the one imperishable product of the age, a priceless heritage of civilization, and given *freely* to all the nations of the Earth!

In view of what has been proved in the researches here sketched, there will in the future be no excuse for our cities on the coasts of deep seas being consumed by conflagrations after earthquakes, for it is shown that all places on the coasts of deep seas are liable to earthquake disturbances, and the people should be prepared for such emergencies by extra and independent systems of water works. If San Francisco had possessed such knowledge before the late disaster, and had had the courage to live up to it, she would not have been laid waste by the fire, nor would the earthquake damages have proved very serious. But human frailty is such that we can learn only by experience. Let us hope that the lesson will not soon be forgotten, and that other cities on the coast will be prepared for possible emergencies.

In the same way there is little excuse for damage by seismic sea waves. If ships put promptly to sea on the first sign of the withdrawal of the water from the shore, they will usually be safe, and can ride securely over the waves due to the sinking of the sea bottom; whereas if they remain in the harbor they are almost sure to be stranded and perhaps destroyed, with enormous losses of life and property.

The researches of science therefore have an eminently practical and humane value, in addition to their purely philosophic interest. The preservation and promotion of science has therefore become one of the highest duties of the state; for the discovery of natural laws is really necessary to the protection of the people and the preservation of civilization.

Naval Observatory,
Mare Island, California,

CHARLES AUGUSTUS YOUNG.

JOHN M. POOR.

For Popular Astronomy.

Charles Augustus Young, Professor Emeritus of Astronomy in Princeton University, one of America's most distinguished astronomers, died at Hanover, New Hampshire, after a brief attack of pneumonia, on January 3, 1908. Though frail of body through disease which had been making its inroad during recent years and though bowed with grief at the death of his wife in 1901 and more recently by that of his daughter, each after long illness, his failing strength prevented him from entering into life about him but a few days before the end came.

His retirement from active service after twenty-eight years as Professor of Astronomy at Princeton in 1905 and his return to Hanover, his native village, the college community of his early years, were made the occasion for placing before the alumni and friends of Dartmouth College substantially the following account of his life, which through personal interests or those of his relatives was for nearly a century closely interwoven with the affairs of the College. It has seemed that this sketch, though written for another purpose, might be of interest at this time to the wider circle of readers of Popular Astronomy.

Immediately upon his resignation from Princeton men of science, men of letters and men of affairs, as well as trustees, faculty and students of the University with the townspeople of Princeton, his neighbors, gave expression to their admiration and appreciation for Professor Young, "Twinkle" as he had been fondly nicknamed by the students. One and all tried to show an indebtedness for some good that he had brought into the life of each, for his simple life free from all conceit and ostentation was a lesson to all about him, as they saw him quietly and modestly coming and going, thinking and speaking good of all. As teacher, investigator, adviser, friend and neighbor, Professor Young was loved.

Professor Young's resignation from active service was submitted to the trustees of Princeton University in December 1904 to take effect the following June. It was accepted, and a minute expressing the high regard of the trustees for him and their sincere regret at his departure was entered on their

records, while he was made Professor Emeritus with a liberal salary. At once the University began to show its feeling. His class in astronomy called at his home and presented a loving cup. Mr. Robert Bridges of New York, a former student published in the *Sun* the following lines which deeply touched Professor Young:

THE ASTRONOMER.

The destined course of whirling worlds to trace:
To plot the highways of the universe,
And hear the morning stars their songs rehearse,
And find the wandering comet in its place:
This was the triumph written in his face
And in the gleaming eye that read the Sun
Like open book, and from the spectrum won
The secrets of immeasurable space!

But finer was his mission to impart
The joy of learning, the belief that law
Is but the shadow of the power he saw
Alike in planet and in throbbing heart—
The hope that life breaks through material bars,
The faith in something that outlives the stars!

Members of the faculty and board of trustees joined with some friends in giving at the Princeton Inn a formal dinner, at which Dean Andrew F. West was toast-master and the toasts were responded to by members of the faculty and board of trustees who had been invited to speak.

President Wilson and Ex-President Patton spoke of the fame that Professor Young had brought to Princeton, and of his remarkable scientific attainments, coupled with his extreme modesty and piety. Mr. Cleveland found it impossible at the last moment to attend the dinner, but he sent the following letter, in response to the toast, "He never sold the truth to serve the hour."

Princeton, May 17, 1905.

Professor Andrew F. West,

My dear Professor:

I feel that I am deprived of a great gratification by my inability to personally participate in the occasion which is to voice the affectionate farewell of the Faculty of Princeton University to the most distinguished of their number.

I hope, however, I may be allowed to express to those who love and admire Professor Young, my sure conviction that nothing can be said by them more completely embodying the exalted nobleness of the man they have assembled to honor, or more prophetic of his everlasting fame, than the words: "He never sold the truth to serve the hour." His scientific achievements will during a long future illumine the world of progress and research; thousands whom he has guided to the height of knowledge will remember him and bless him; his kindly nature and beautiful example will bear fruit in the lives and character of all brought within the circle of their ennobling influence; but in the infallible and indelible record of God, and on the hearts of those who in all time to come shall learn his life, there shall be written this clearest and most conclusive testimony to his greatness and goodness: "He never sold the truth to serve the hour."

Yours truly,

GROVER CLEVELAND.

M. Taylor Pyne, speaking for the trustees of Princeton University said in part:

"Professor Young has been with us twenty-eight years, and he is leaving with the esteem and best wishes of every one of us. Never has his name been mentioned in my hearing except with respect, love, and admiration. I hardly think he knows how very fondly he is esteemed by us all, and how much we appreciate him. I hope he will some day realize what it means to the students who have come out from under his instruction and have watched him studying and mastering great problems, keeping always a firm faith in his maker."

Professor W. F. Magie spoke as a former pupil of Professor Young, and paid a high tribute to his skill as a teacher, and Professor Henry Van Dyke recited the following poem which he had written for the occasion:

STARS AND THE SOUL.

TO CHARLES A. YOUNG.

"Two things," the wise man said, "fill me with awe:
"The starry heavens and the moral law."
Nay add another marvel to thy scroll,—
The living marvel of the human soul.

Born in the dust and cradled in the dark,
It feels the fire of an immortal spark,

And learns to read, with patient, fearless eyes,
The splendid secret of the unconscious skies.

For God thought Light before He spoke the word;
The darkness understood not, though it heard:
But man looks up to where the planets swim,
And thinks God's thoughts of glory after Him.

What knows the star that guides the sailor's way,
Or lights the lovers' bower with liquid ray,
Of toil and passion, danger and distress,
Brave hope, true love, and utter faithfulness?

But the frail heart that, bearing good and ill,
Holds fast to virtue with a loyal will,
Lends to the law that rules our mortal life
The star-surpassing victory of life.

So take our thanks, dear reader of the skies,
Devout astronomer, most humbly wise,
For lessons brighter than the stars can give,
And inward light that helps us all to live.

The world has brought the laurel leaves to crown
The star-discoverer's name with high renown;
Accept the flower of love we lay with these,
For influence sweeter than the Pleiades.

For though the hour has come when we must part,
That influence long shall live within our heart,
And we shall know thee travelling on thy way
Into the brightness of a heavenly day.

Professor Cyrus F. Brackett spoke of Professor Young's place in science, and on behalf of the faculty presented to him a handsome silver loving cup. Then the toast of the evening was proposed standing, Professor Young expressing his thanks in a few characteristically modest words, during which he took occasion to pay a graceful compliment to his successor in the chair of astronomy, Dr. Edgar Odell Lovett. The dinner closed with the singing of Auld Lang Syne and Old Nassau, and a triple cheer for Professor Young.

At Commencement in June 1905 the degree Doctor of Laws was conferred by Princeton on Professor Young, who was thus introduced by Dean West:

"Charles Augustus Young, until to-day the Professor of

Astronomy in Princeton University. A pioneer in astronomical spectroscopy and photography; discoverer of the bright line in the spectrum of the corona; observer of the flash-spectrum at the beginning and the end of totality, thus becoming the discoverer of the 'reversing layer' of the solar atmosphere; preparer of a catalogue of bright lines in the chromosphere spectrum; first observer of remarkable solar eruptions; demonstrator of the resolution of Lockyer's 'basic lines' and of the sunspot spectrum; author of books and many papers, some of them translated into various languages; observer or conductor in eight astronomical expeditions in this and other lands. His work is an enduring part of the history of astronomy;—a great discoverer, a great teacher, our dear and venerated colleague, whose knowledge is inferior only to his gentle modesty. And so, dear friend, hail and farewell! In the old words: *Di tibi dent annos; de te nam cetera sumes*,—'God grant thee many years. All else thou shalt have in thyself.' "

As he came forward to receive the degree, the students in the body of the house arose and gave a triple cheer for Professor Young.

Professor Young used to say that teaching was his vocation and research his avocation. But among the many who were his students or who profited by his encouragment and advice, several of whom hold high positions as directors of observatories, probably very few can hope to contribute more to science by invention and discovery than he to say nothing of his teaching. He taught astronomy to fifty-one classes of college students, and thousands heard his lectures or read his text-books.

It has been said that Professor Young "was to the manor born." His maternal grandfather, Ebenezer Adams, one of nineteen children, was born on a farm at New Ipswich, New Hampshire, in 1765, and because of the moderate circumstances surrounding him delayed until nearly twenty-two years of age his entrance to Dartmouth College, from which he graduated with honor in 1791. After teaching eighteen years, he was in 1809 called to Dartmouth as Professor of Languages, but in the following year was made Professor of Mathematics and Natural Philosophy. This position he held until his resignation in 1833, when he was made Professor Emeritus. He was a faithful, patient, earnest teacher of varied attainments, personally interested in the welfare of his students to whom he imparted information clearly and easily. He in no small

way aided in bearing the burdens of administration and for more than two years during the sickness and after the death of President Brown he acted as president of the College. At his resignation in 1833, he was succeeded in the professorship by the father of Professor Charles A. Young, Professor Ira Young, who soon after his appointment married Eliza, youngest daughter of Professor Adams.

Professor Ira Young was born at Lebanon, New Hampshire, in 1801. His want of means and his father's refusal to allow him time before his majority prevented him from entering College before twenty-three years of age. He graduated from Dartmouth with high rank in 1828. In 1830 he became tutor in Dartmouth College and in 1833 he accepted the Professorship of Mathematics and Natural Philosophy. In 1838 his chair was changed to that of Natural Philosophy and Astronomy, a position which he held until his death in 1858. He was a master of the science and literature of his department to which he had given special attention while in College. A thoroughly earnest seeker for truth, he developed a like spirit in his pupils, and like this predecessor he was a born teacher, possessing the power of clearly stating his knowledge and, mindful of his own youthful difficulties, he was habitually patient in presenting his facts after reducing them to their simplest terms.

In 1853 he visited Europe in the interest of Shattuck Observatory, which was built and equipped with funds obtained largely by his own efforts. He was accompanied by his son, Charles A., then in his senior year in Dartmouth. Professor Ira Young died rather suddenly in 1858, and was succeeded by the late James W. Patterson as Professor of Astronomy and Meteorology, who was in turn succeeded by Professor Charles A. Young as Appleton Professor of Natural Philosophy and Professor of Astronomy in 1866.

Professor Charles A. Young was born at Hanover, New Hampshire, December 15, 1834. Unlike his grandfather and his father he was ready for college at fourteen, having been his father's assistant in surveying and in the chemical and and physical laboratories since ten years of age. He entered Dartmouth in 1849 and graduated in 1853 with honor at the head of his class of fifty men. While a student he was not interested in college politics or society matters. His nickname was *Adulescentulus*. He was a member of the Social Friends, the Theological Society, corresponding to our Y. M. C. A., and

the Society of Inquiry, which was composed of students interested in missionary work. As before stated he visited Europe with his father during the spring and summer of 1853, thus being absent from the Commencement exercises of his class, but his diploma was granted with the rest as his work had been "made up" in advance. Soon after graduation he made his first contribution to scientific literature by publishing in a volume entitled "New Hampshire As It Is" the article on "Climate" for which he received ten dollars. From 1853 to 1855 Professor Young taught classics at Phillips Academy, Andover, Massachusetts, when he entered Andover Theological Seminary where he spent one year, giving part time for half a year to teaching classics in the Academy. In 1856 came the call to Western Reserve College at Hudson, Ohio, and Professor Young gave up his plans for missionary work to accept the Professorship of Mathematics, Natural Philosophy, and Astronomy, at that institution, beginning his work in January 1857. In the following August he married Miss Augusta Mixer, grand-daughter of Hon. Samuel Morrill of Concord, New Hampshire, with whom she had lived since the death of her father soon after her birth. To Professor and Mrs. Young were born while in Hudson three children, the late Mrs. Clara Y. Hitchcock, wife of the late Hiram A. Hitchcock, who was for eight years until his death in 1895 Associate Professor of Civil Engineering in the Thayer School at Hanover, New Hampshire, Charles I. of Philadelphia, who is an engineer in the Westinghouse Electric and Manufacturing Company, and Frederick A. of Washington, D. C.

At Western Reserve Professor Young furnished time-service for Cleveland, his system being one of the earliest in the country, and during several summers worked in the U. S. Lake Survey in determining telegraphic differences of longitude. For one year he held his only political office as common councilman of Hudson, from a ward composed largely of students. In 1862 in reponse to a call from the governor of Ohio for three months' volunteers, the students' military company offered its services which were accepted, and it became Company B of the 85th O. V. I. with Professor Young as captain. For a time it did duty at Camp Chase in guarding confederate prisoners, and later went as escort for two thousand prisoners to be exchanged at Vicksburg. "Captain" Young returned to academic duties with impaired health.

As early as 1863 he was offered the Professorship of Math-

ematics in Dartmouth College, which he declined; but in 1866 came the call to become Appleton Professor of Natural Philosophy and Professor ot Astronomy, a position which he accepted and returned to the home of his boyhood to occupy the chair held by his father until 1858. At about this time, that keen mechanical ingenuity so characteristic of all his work manifested itself in the independent invention and publication of plans for a printing chronograph.

At this point begins the conspicuous period of his career. Upon returning to Dartmouth he began at once his investigations in spectroscopy to which he brought enthusiasm, untiring energy and devotion to work, keen powers of observation and analysis, a vigorous active mind, and rare mechanical skill. He saw the opportunity in spectroscopy and advised that the comparatively large Appleton fund, established in 1845, be spent in equipment rather than buildings. His advice was followed, and within a few years there came that series of investigations and discoveries which placed him at once among the most distinguished astro-physicists of the world, and brought upon the observatory and laboratory an international reputation. Though always interested in mathematical astronomy so that he was a master in analyzing and stating complex ideas there involved; and though his "true eye" brought him a high rank as an observer with micrometer and transit instrument, yet it was above all as an astrophysicist and authority on the Sun that Professor Young was celebrated and for which he was most highly honored.

After corresponding with Professor Cooke of Harvard, Professor Young obtained from Alvan Clark a spectroscope and through Professor Alexander, of Princeton gained an opportunity to observe the eclipse of 1869 at Burlington, Iowa. Professor Young's work consisted in spectroscopic observations of the contacts, first made at this eclipse by him, and his discovery of the green line of the corona spectrum—seen also by others with less powerful instruments—which he wrongly but quite naturally identified with Kirchoff's "1474," a line which he had independently discovered not long before in the chromosphere spectrum. This error remained uncorrected until the eclipse of 1898 when Sir Norman Lockyer and Professor W. W. Campbell independently showed that the wave length of the corona line was slightly different from that of "1474."

This success resulted in the immediate construction, ac-

cording to plans suggested by Professor Young, of a "prominence" spectroscope, and an invitation to observe the eclipse of 1870 at Jeres in Spain, where he observed the "flash" spectrum and discovered the "reversing layer," the most prominent event of the eclipse, thus described in his own words: "As the crescent grew narrower . . . . . the dark lines of the spectrum, and the spectrum itself, gradually faded away, until all at once, as suddenly as a bursting rocket shoots out its stars, the whole field of view was filled with bright lines more numerous than one could count."

The wholesale reversal of the spectrum was long questioned, and especially by Sir Norman Lockyer, so that for more than a quarter of a century Professor Young waited for confirmation, which finally came from a photograph by Mr. Shackelton, one of Sir Norman Lockyer's assistants at the eclipse of August 9, 1896. Just before the eclipse Sir Norman had said in *Nature*, "To my mind the reversing layer is dead and buried already, but may the fates be propitious on the 9th and enable us to place the wreath on its tomb." After the reversing layer had been established by Mr. Shackelton, Sir William Huggins in writing Professor Young took occasion to quote from "Old Mother Hubbard," how she

"Went to the joiner to get him a coffin
And when she came back the dog was a-laughing."

The same year (1870) also saw the first photograph of a prominence, which was made with the prominence spectroscope of Shattuck Observatory. After his return from the Spanish eclipse of 1870, Professor Young raised the funds necessary for mounting a 9¼-inch lens by Clark in the dome previously occupied by a 6¼-inch Merz lens. In 1871 he published his explanation of the spectrum of the solar corona, and on September 7, 1871, he observed the most remarkable outburst on the Sun which had been seen up to that time. In the following summer he undertook under the auspices of the United States Government an investigation of the advantages of observing stations of high altitude. He visited Sherman, Wyoming, where 170 new chromosphere lines were added to the one hundred already catalogued at Shattuck Observatory, and at this station were also observed those solar disturbances which when compared with the magnetic records at Greenwich did much to establish the probability of some connection between terrestrial magnetism and solar conditions.

The first aplication of the diffraction grating to astronomical work was made by Professor Young in 1873. In 1874 he was asked to take charge of a party which was to visit Kerguelen Island for observations of the transit of Venus, but this he was unable to accept because of the long absence from the college which would be necessary. He was, however, able to join the party of Professor James C. Watson, which successfully observed the transit at Peking, a large number of photographs being secured; but hardly had the observers finished their work when there appeared clouds which together with a dust storm closed in upon them, entirely obscuring the Sun. One possible disaster had been escaped by a narrow margin, but not all dangers had yet been passed, for within a few days the Emperor of China fell ill with smallpox, and the astronomers from America were advised by the American legation that inasmuch as the foreigners who had been dealing with spots on the Sun might be held responsible for the spots on the Emperor's face it was advisable that the party leave as soon as possible. They therefore immediately began their journey homeward in carts in which they travelled seventy miles, for the most part by night, to Tientsin.

While at Peking Professor Young, in observing transits for time with a "broken" transit instrument, detected certain residuals in his results which he finally traced to flexure of the axis of the transit instrument, a matter which has since received theoretical treatment. In 1876 Professor Young first measured the rotation of the Sun by means of the diffraction grating from displacement of lines in the solar spectrum.

Professor Young had been at Dartmouth little more than a decade when he was called to Princeton as Professor of Astronomy, a position which he accepted. During his years at Dartmouth, besides accomplishing what has already been recorded together with teaching, he had written perhaps one hundred papers, for the most part on scientific subjects, and published his first book "The Sun," the reproduction of a lecture delivered at New Haven in 1872. This book is not to be confused with that of the same name published nine years later. He had begun in 1868 his lectures on physics and astronomy (each given in alternate years) at Mount Holyoke Seminary (now College), which were continued until 1883, after which until 1903 he lectured biennially on astronomy. About 1870 he began those public lectures for which he later became so famous. From 1872 until 1898 he lectured biennially at Bradford Academy,

Bradford, Massachusetts. In 1873 and again in 1875 he lectured on physics at Williams College, and he lectured at numerous schools for young women both before and after leaving Dartmouth. While at Dartmouth several offers of professorships were received from leading colleges and universities. In 1869 he was elected an associate of the American Academy of Arts and Sciences, and about 1872 he was made an Associate of the Royal Astronomical Society, a member of the National Academy of Sciences and also of the American Philosophical Society, and in 1876 he was Vice-President of Section A of the American Association for the Advancement of Science. He received the degree Doctor of Philosophy from the University of Pennsylvania in 1870, from Hamilton College in 1871, and in 1876 Wesleyan conferred npon him the degree Doctor of Laws.

At the time of his call, Princeton's chief astronomical equipment was the three-inch Fraunhofer lens now used as a collimator, but within a year the students' observatory was built and liberally equipped with the best instruments for teaching, including a telescope by Clark slightly larger and much better than the one left at Dartmouth, together with the necessary spectroscopic apparatus, and in 1882 the large Halsted Observatory was equipped with a telescope of twenty-three inches aperture, by Clark, and the most powerful spectroscopic apparatus then to be procured. From 1878 to 1880 he undertook an examination of Sir Norman Lockyer's "basic lines" and showed that they were double and not to be attributed to the same element. In 1878 he conducted a party of Princeton men to Denver to observe the eclipse of that year. The weather was good but no especially important results were obtained. In 1887 he visited Russia to observe the eclipse near Moscow, but rain entirely prevented observations, and again in 1900 he organized a party which successfully observed the eclipse at Wadesboro, N. C.

Among other investigations which engaged his attention while at Princeton were spectra of sun-spots, formation of of sun-spots, spectra of comets, the spectrum of Venus, the spectrum of Nova Aurigae, revision of his catalogue of chromosphere lines, color correction of certain objectives, polar compression of Mars, polar compression and belts of Uranus, and measurements of double stars (not yet published), and in 1882 the transit of Venus was elaborately observed, both visually and photgraphically, at Princeton in coöperation with

the various government parties. Early in his work at Princeton he completed his plans, already begun at Dartmouth, for a clock escapement which should unlock and receive its impulse at that point in its oscillation where disturbances have least effect on its natural period. This escapement has been giving good service in the standard clock at Princeton for twenty-eight years. A modification of a suggestion by Professor Young has been adopted in the driving clocks used on many recent American telescopes. Professor Young's observational work ceased only when his own failing health and that of Mrs. Young made his frequent visits to the observatory impossible.

In 1881 he published in the international Scientific Series his book entitled "The Sun." This book, containing a complete summary of existing knowledge of the subject, has run through numerous editions and has been translated into several languages. In 1889 he published his first text-book "General Astronomy," in 1890 he published "Elements of Astronomy," and "Uranography," in 1891 "Lessons on Astronomy," and in 1901 his "Manual of Astronomy." All except the last have run through numerous editions and the total sales amount to approximately 130,000. He published a large number of scientific papers, with many magazine and newspaper articles, and from 1890 to 1903 he gave perhaps a dozen courses of university extension lectures as well as many single lectures.

He received the degree Doctor of Laws from Columbia in 1887, Western Reserve 1893, Dartmouth 1903, and Princeton 1905. In 1884 he delivered the address of the retiring president at the meeting of the American Association for the Advancement of Science. In 1887 he attended the meeting of the British Association for the Advancement of Science and was made a foreign correspondent, and at about the same time became an honorary member of the Manchester Literary and Philosophical Society. In 1896 he became a member of the Cambridge (England) Philosophical Society; but his greatest honor came in 1891 when he received the Janssen Medal from the French Academy of Sciences for his spectroscopic investigations, and especially for the discovery of the reversing layer.

Upon his return to the scenes of his boyhood he immediately took part as far as health permitted in the activities about him. Though greatly regretting it, he was compelled to give into the hands of others work which he had defin-

itely planned for the years of his retirement. At times confined to the house, his health had during recent months greatly improved so that he was shut in from the Sun he loved and to the knowledge of which he contributed so much but a few days before he gently passed away.

The funeral was held on Sunday afternoon, January 5. Mr. F. L. Janeway, Pastor of the College Church, a former pupil at Princeton, conducted the service, a few friends sang favorite hymns, and Doctor Leeds, Pastor Emeritus of the College Church, spoke most fittingly out of a long and intimate friendship. The bearers were Professor Edgar Odell Lovett, his successor in the chair of Astronomy at Princeton, Professors John K. Lord, Charles F. Emerson and John M. Poor of the Dartmouth faculty. Interment took place in the old cemetery near the house in which he was born.

At the meeting of the faculty of Princeton University immediately following Professor Young's death the following resolutions were passed:

Resolved: That the faculty have heard with profound sorrow of the death of Professor Charles Augustus Young. Alike in gifts and in character he had always seemed to them the ideal man of science. His transparent honesty, his unaffected modesty, his insight into principle, and his achievement in discovery united to give his career not only distinction but also grace and beauty; and his qualities as a man won for him our love as well as our admiration.

He died full of years and of honors, but his death could at no time be less than a great bereavement; and the faculty extends to his sons, his sister and all who have been nearest to him in life their deepest sympathy.

Resolved: That the Clerk of the Faculty be requested to send a copy of these resolutions to Professor Young's family and to *The Princeton Alumni Weekly*.

Professor Young is survived by his two sons, Charles I., of Philadelphia and Frederick A., of Washington, D. C., his grandson Charles Y. Hitchcock of Hanover, N. H., and also by his brother Albert A., of Winona Lake, Ind., and his sister Mrs. Adeline E. Procto. of Hanover, N. H.

Shattuck Observatory,
Hanover, New Hampshire.

PLATE XIII.

HENRY M. PARKHURST,
1825-1908.

HENRY M. PARKHURST.

J. A. PARKHURST.

FOR POPULAR ASTRONOMY.

After a long and exceedingly active life the subject of this sketch passed away at his home in Brooklyn, New York, on January 21, 1908, after a brief illness. Early in life he was attracted to astronomy, and though his versatile mind could not be confined to any one branch of science, astronomy was his favorite, and the amount of solid and useful work which he accomplished entirely as an amateur would be a credit to any professional astronomer. He was a frequent contributor to the *Sidereal Messenger*, and *Astronomy and Astro-Physics*, so that it seems fitting that a sketch of his life and work should be given in *Popular Astronomy* as an inspiration to those amateurs who are taking up the work which has been laid down by the former generation.

Born in New Hampshire March 1st 1825, he became the first American phonographic reporter. From 1848 to 1854 he was Chief Official Reporter for the United States Senate, and as such reported Daniel Webster's speeches. An idea of the far-reaching influence of this young reporter on American business life can be had by considering the fact that he was first to introduce women to the profession of stenography. Later he followed his profession in New York City, being for twenty years official reporter for the Superior Court.

Before describing his astronomical work, brief mention must be made of some of his activities in other directions, as these will help us to appreciate his ingenuity, his alertness of mind, and the broad view which he had of life. As a young man he was interested in music and in 1851 he invented and constructed a new "Harmonic organ" and devised a new musical notation. In 1855 he patented a new form of proportional dividers. He published papers on "A New Currency" (1848), "A New Mode of Minority Representation," many papers in the *Photographic Times*. That he had the spirit and courage of a reformer we have abundant evidence throughout his life. His work as a stenographer early called his attention to the faults of the English language. Not content with half-way measures of reform, as early as 1845

he invented a universal language, and throughout his life he was an earnest and consistent advocate of spelling reform. For nearly forty years he published "*The Plowshare*," putting it in type and printing it with his own hands, using an alphabet in which each character stood for a single sound and each sound was represented by a single character. Similar reform principles appear in his "Duodecimal Metric System" published in 1872, and the "Duodecimal Notation" in 1874. His "Stenophonography," a modification of Pitman's phonography, was put in type and printed by himself. When we consider that these were all products of his "leisure" time, outside his professional duties by which he gained his livelihood, we must admit that his was a busy life. This opinion will be further strengthened when we come to consider his

ASTRONOMICAL WORK.

He became interested in astronomy at the age of six, and at seventeen he invented what he called the "Elongator," a concave lens for lengthening the equivalent focus of the telescope. At eighteen he observed the great comet of 1843 and computed its orbit by a method of his own devising. When this was published in the *American Almanac* of 1844 his name was mentioned among the "eminent astronomers" who had computed the orbit. His close watch on the sky is shown by his independent discovery of Donati's comet in June 1858 while it was still a faint object, and another similar discovery in 1863. His skill in observing is shown by his success with the transit of Mercury in 1868, for which his observations were allowed greater weight than any others in America. Before this time he came to realize the importance of having a regular line of work which should be continued over a term of years. This was an advanced position to be taken by a busy professional man, and was worthy of an astronomer having a fixed position and salary. Appreciating the need of better star-maps as a foundation for any advance in stellar astronomy, he says—"In September or October 1856 I completed the invention and construction of the first Star-Mapper ever devised. A roll of paper being moved as in telegraphing, to represent the right ascension, a pen moving at right angles to the motion of the paper, and connected by levers with a pointer moving in the focus of the eyepiece, marked the position and the estimated magnitude of each star of the zone. In six years I had thus mapped 100,000 stars. I discovered Galatea by finding it on

my maps two months before the news of its discovery by Tempel reached this country."* It is a curious coincidence that the invention and use of the "Star-Mapper" synchronized with the first publication by Argelander of a notice of his great project of the *Bonn Durchmusterung*,† which absorbed the energies of the Bonn Observatory for years. The third part of the *Durchmusterung*, completing the northern heavens, was published in 1862. In these three parts the workers at Bonn had mapped 324,000 stars, while our amateur, after office hours, had mapped 100,000! If American astronomy could have had the same support which was given to the science in Germany, it is reasonable to suppose that we might have shared with that country the glory of such great works as the *Durchmusterung*, but in those troublesome times it could not be expected.

From mapping the positions of stars and estimating their magnitudes, the next logical step was to measure their magnitudes; so we find that from the sixties onwards, stellar photometry occupied more and more of his astronomical activities, and after 1883 became his specialty. It is difficult for us to realize the confusion which existed in stellar photometry a generation ago. The scale of the Bonn Durchmusterung was only one of many in use, and that was founded on eye-estimates and the limit of vision of a 3-inch comet seeker. Pogson's ratio, giving the relation between the light of stars of adjacent magnitudes, had been suggested but not generally adopted, consequently there was no guide for the magnitudes of the fainter telescopic stars. Argelander's 13th magnitude corresponded approximately with the 16th of Herschel and Smyth and 11th of Struve. With characteristic good judgment Parkhurst adopted Pogson's ratio (using it after 1863) and proceeded to devise instruments for the accurate measurement of magnitudes. In the *American Journal of Science* for January 1870 he described two photometers: a "Photomapper" which was a combination of wedge photometer and the "Star Mapper" already described, mapping positions and magnitudes at the same time; and a "Disk Photometer" for the brighter stars.

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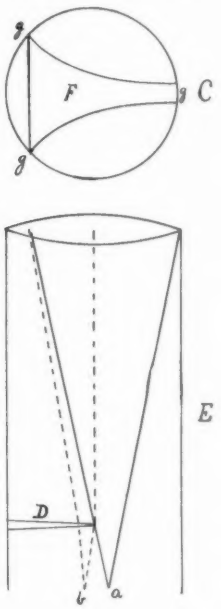
* For description of the "Star Mapper" see *American Journal of Science*, September 1869.

† *Anzeige* von einer auf der Königlichen Univer. Sternwarte zu Bonn unternommen Durchmusterung des nördlichen Himmels als Grundlage neuer Himmelscarten. Bonn, 1856. See *Bonner Beobactungen*, Bd. III, Einleitung.

He says: "By the latter method I expand the stars into disks by drawing out the eyepiece beyond the focus, until a portion of the disk, shining through an aperture in the field of view, shall be exactly equal to an adjacent luminous disk." During the years 1869-71 he measured with this photometer the light of 82 naked-eye stars, 19 of those most frequently observed having a mean error less than 0.03 and 31 others less than 0.10 magnitude. Constantly experimenting he devised and used; Reduced apertures, 1859; Bar photometer, 1860; Polarization photometer, 1873; Shade photometer, 1873; Immersion photometer, 1876; Variable-aperture photometer, 1878; Deflecting photometer, about 1883. The greater part, and the best, of his photometric work was done with this last instrument, used on a 9-inch Fitz refractor of 112 inches focal-length. For a time this was supplemented by a wedge for the fainter stars. The deflecting photometer is described by him in the *Annals of the Harvard College Observatory* Vol. 18, page 30, and by Müller in his *Photometrie der Gestirne* page 177. It was his favorite apparatus, chosen by a long process of exclusion, because it satisfied two important requirements: First, it was free from the disturbing effects of varying field-illumination, a fatal defect with the extinguishing wedge photometer. Second, it enabled him to make and record his observations without an assistant and without exposing his eye to light. Its principle is shown in Figure 1. The objective (shown in plan at C) is covered by a cap whose opening, F, is bounded by logarithmic curves *ggg*. Inside the telescope tube (shown in section at E) there is supported near the focus a deflector D, a rectangular piece of clear glass whose surfaces make a small angle with each other. Suppose the telescope at rest and pointed south; a star enters the field and until its image reaches the position *a*, the cone of rays, everywhere the shape of the opening F, is not interrupted by the deflector D. But as the image moves from *a*, a portion of the cone passes through the deflector and the rays are refracted, forming a second image of the star, as at *b*. As the image *b* grows brighter, *a* becomes fainter and finally disappears. Since the cone of rays is bounded by logarithmic curves, the change in magnitude is directly proportional to the time elapsed. Since *a* disappears against an unchanged background, there is no error from varying illumination. With this arrangement the diurnal motion causes a change in an equatorial star of one magnitude in about 40 seconds,



so that if the time of disappearance is known within a second, the magnitude is given to 0.025. It is a characteristic of Parkhurst's work that it is carefully guarded against systematic errors, he did not shun the labor necessary to ascertain and allow for them; while his trained skill in observation reduced the accidental errors to small amounts.

Results of Photometric Work.

These may be divided into: 1st, Long period variables; 2nd, Asteroids; 3rd, Comparison stars for both.

1st. *Long period variables.* He began this work in 1883 and continued it till the fall of 1907. The results of the first ten years' work were published in the *Annals of the Harvard College Observatory*, Vol. xxix, pages 89 to 170 (including his first catalogue of comparison stars), comprising observations of 96 variables, and measures of nearly 3000 comparison stars. From 1884 to 1890 he colaborated with Mr. John H. Eadie of Bayonne, New Jersey, who observed the variables in their brighter stages with his 3-inch telescope, and some years later with Arthur C. Perry. Stand-

ard stars from the Meridian Photometry (*Harvard Annals* xxiv) were used to reduce the results to magnitudes. The tables give concisely the dates and observed magnitudes, and the mean light-curve of each variable, but the separate maxima and minima are not given. Beginning with 1893 he published the results in the *Astronomical Journal* under the title: "Notes on Variable Stars." No. 1 of this series appeared in Vol. xiii, page 167, and No. 41, the last, in Vol. xxiv, page 202. For each star the Julian and calendar dates of maximum or minimum are given, the magnitude, the number of the epoch and the correction to the ephemeris. In a separate table the individual observations are given in a form similar to those in the *Harvard Annals*. As data for the comparison stars accumulated, improved values were given in the "Notes;" and his principal object became the improvement of these standards to the highest possible degree.

2nd. *Asteroids*. Measures of the brightness of a selected list of asteroids were begun in 1887, were very numerous in the years 1887-88-89, and were continued regularly for a smaller list till 1907. His results for 1887, with a complete statement of methods of observation and reduction, were published in the *Harvard Annals* Vol. xviii, pages 29 to 72. The list included 18 asteroids and 598 complete observations were made, nearly all with the Deflecting Photometer. Auxiliary tables for computing the reductions are given, and a thorough discussion of the sources of error, corrections, and significance of the results, make the work a model. After reduction to distance unity, and correction for defect of illuminated disk, his results indicated unmistakably the need of another correction for phase, which was a linear function of the angle at the asteroid between the Sun and the Earth. The correction is pP where P is the angle expressed in degrees, and p a constant for each asteroid, but ranging from 0.02 to 0.05 for the different ones. The values of this coefficient agree closely with those found by Müller at Potsdam* during the years 1881-6. The results for 1887-88 are published in Vol. xxix of the *Harvard Annals*, pages 65 to 88, giving improved values of the mean magnitudes and reduction constants. In all there were 3002 observed extinctions of 36 asteroids.

The importance of these observations (including those by Müller, the only other extended series) can hardly be over-estimated. The light of the asteroids, coming from the Sun, is

* *Photometrie der Gestirne*, page 377, *Potsdam Pub.* Vol 8, page 355.

dependent only on the solar constancy for its uniformity. (This neglects small changes due to possible rotation, which will be averaged out of even a short series of observations). The uniformity of this solar "constant" can best be tested by comparison of asteroids and stellar standards; or, admitting equal value to the pyrheliometer method, the two will furnish valuable checks on each other.

On the other hand, assuming the solar constancy, the asteroids furnish ideal *standards for stellar magnitude.* This thought was uppermost in Parkhurst's mind for the last twenty years of his life, and he bent every energy to the work of improving the values of his asteroid standard magnitudes. To appreciate the advantages of such standards we must remember that the greatest source of error encountered in the attempt to form a working catalogue of standard magnitude stars scattered over the heavens, is the varying transparency of the sky between regions even a few degrees apart. As an example of attempts to eliminate these errors, Müller and Kempf at Potsdam, selected a list of 144 stars covering the northern sky, compared each repeatedly with six neighboring stars, and by laborious methods formed an excellent standard catalogue. But no sooner was it completed than they found that one of their standards was really variable! As a matter of fact it is as difficult to prove the constancy of each of these stars as it would be to establish the constancy of the light of the Sun, and as a consequence, *all the asteroids.* Furthermore, the motion of the asteroids tends to correct the "local" errors referred to above, since they are traveling standards, and can be compared, not only with stars in different regions, but with each other. Parkhurst's ideas and results cannot be better stated than by an extended quotation from a letter to the writer, dated January 25, 1904.

"We have as yet no standard for star brightness which is reliable except my asteroid standard. Even Müller and Kempf and the Meridian Photometer Catalogues are unreliable, because the stars are all liable to vary, and even if several stars are selected to balance out the errors, we can never tell which ones are most liable to be wrong, or how great the error may be. But I think the asteroids are immutable, except Eros and possibly some others which vary slightly from rotation, and which are safe standards in a series of observations. Hitherto my idea has been that my 24 confirmed asteroids make a combined standard. I have just reached the conclusion that *each*

of the 24, excepting Eros, is a standard of itself, and all adjusted in unison; so that all that is needed is to take the nearest of the 24, and using that as a standard the result will be more accurate than any set of catalogue standards can be. For instance using Vesta alone is more reliable than making the same number of comparisons with stars from Harvard or Potsdam, the error being only the error of observation, the error of the standard being inappreciable. That is, I have already reached the point where the error of the standard is less than the error of observation. To illustrate, it is safer to take the diameter of Jupiter from the ephemeris than to take it from the most careful measurement.

I am making small changes in my asteroid constants, but they result from enlarging the number of confirmed stars which underlie the standards, and the changes in the particular stars which happen to come into the list. Instead of a list of 24 I now reduce my list to 12, selecting the 12 most fully observed, each of which is a standard of itself. I shall keep the 24 under observation and use them all in conjunction; but largely in order that I may properly apply the minute changes of the constants and preserve a record of the foundation of such changes.

I will copy my short list of constants, in order that you may preserve it for publication after I have finished work upon it, adding the latest reductions of the other 12, of which I shall make it a point to send you copies for this purpose, in order that finally there shall be no appreciable difference between results from individual asteroids of the list. Please preserve this list and keep with it any changes I may hereafter make in it. I find that I seldom have occasion to modify the last decimal more than 1."

H. M. Parkhurst's Final List of Asteroid Constants.

Epoch 1901.

No.	G°	p	No.	G°	p	No.	G°	p
4	4.12	0.023	433	9.78	0.037	16	5.93	0.051
1	3.61	0.043	7	5.84	0.018	3	6.05	0.020
20	6.63	0.035	2	4.32	0.036	5	7.06	0.037
11	6.93	0.022	8	6.63	0.031	12	7.18	0.024

In this table G° stands for the stellar magnitude of the asteroid, in the system of the Harvard Meridian Photometry, reduced to distance unity from the Sun and the Earth. As before stated, p is the coefficient of the phase correction,

and is to be multiplied by the angle at the asteroid between the Sun and the Earth, expressed in degrees.

This confessedly incomplete sketch cannot do justice to its subject. He possessed a true scientific spirit, combining high ideals, ability and industry. In the opinion of those competent to judge, his results place him in the front rank of workers in stellar photometry. Unfortunately, the writer cannot speak from personal acquaintance, but wishes to acknowledge his indebtedness for much assistance in photometric work, through a correspondence lasting over fourteen years.

Yerkes Observatory,
Williams Bay, Wisconsin.
February 1908.

THE SUN'S MOTION IN SPACE AND THE FIXED STARS.

W. H. S. MONCK.

FOR POPULAR ASTRONOMY.

In 1902 I contributed to POPULAR ASTRONOMY an article in which I contended that our estimates of the Sun's motion in space were influenced by the motion (revolution?) of the Galaxy to which most of the observed stars belonged. I inferred this upon Bossert's Catalogue, chiefly as regards the right ascension of the Stars. I found that the two neutral points which separated the region in which increasing right ascensions prevailed from that in which diminishing right ascensions prevailed, coincided very nearly with the two points where the Galactic Circle crossed the equator—that the neutral point between the sixth and seventh hours of right ascension was sharply defined, the Galaxy being narrow and well-defined at this point, whereas at the other intersection where the Galaxy is ill-defined and double, the neutral point was similarly diffused: and moreover it seemed to lie between the nineteenth and twentieth hours of R. A., the sky being thus divided into two unequal regions of about thirteen hours and eleven hours respectively instead of two equal regions each embracing twelve hours of R. A. On looking over the recent determination of the proper motions of Bradley's stars I noticed somewhat similar features: and the reader will find further information in the writings of Professor Kapteyn and Mr. Eddington though

the two authors are not in very close agreement as to the direction of the double star-drift. I think however that their researches confirm the idea of a connection between the observed motions and the motion of the Galaxy though we may not yet be able to state exactly what that connection is. The Catalogue of 1186 Carrington Stars contributed by the astronomer Royal of England to the *Monthly Notices* of the R. A. S. for November 1907 seemed to me calculated to throw additional light on the question, for as they are all situated within 10° of the North Pole it appeared probable that they were little influenced by the Galaxy. I accordingly tabulated them hour by hour as regards their proper motions in R. A., omitting those which had none or whose proper motion was not determined, with the following result:

Hour			Stars with increasing R. A.	Stars with diminishing R. A.
0	to	1	39	15
1	to	2	34	7
2	to	3	26	11
3	to	4	20	18
4	to	5	17	28
5	to	6	20	21
6	to	7	17	24
7	to	8	6	31
8	to	9	8	47
9	to	10	11	34
10	to	11	18	38
11	to	12	13	48
12	to	13	16	41
13	to	14	17	44
14	to	15	14	29
15	to	16	25	27
16	to	17	23	18
17	to	18	23	15
18	to	19	37	17
19	to	20	37	11
20	to	21	35	8
21	to	22	26	8
22	to	23	28	15
23	to	24	30	15
	Total		554	571 *

The displacement of the neutral points compared with the results given by Bossert's (or Bradley's) catalogue is here obvious. They here occur about the 4th and 16th hours of R.A., giving about 240° for the R. A. of the Sun's apex which is at least 30° less than that set down in the majority of computations. The neutral points moreover are nearly twelve hours apart thus dividing the part of the sky examined into two

* These figures may not be strictly accurate, but they are very nearly so.

equal regions in one of which increasing right ascensions preponderate while in the other diminishing Right Ascensions form the majority. The total numbers moreover it will be seen are also very nearly equal, whereas in Bossert's Catalogue there were 1450 stars with diminishing R. A. against 1190 with increasing R. A. These more symmetrical results suggest that this catalogue affords a better representation of the Sun's motion (apart from systematic motions among the fixed stars) than is to be found elsewhere, and I think if any astronomer would compute the position of the Sun's apex from this catalogue of stars it would repay the labor. The reader will notice however that (starting from 0^h) *after passing* the two neutral points there is some unsteadiness and fluctuation, as if there was some cause interfering with the Sun's motion and rendering it less effective than might otherwise be expected. Thus the preponderance of diminishing right ascension is by no means well-marked between the fourth and seventh hours of R. A., and shoots up suddenly between the seventh and eighth. Even the figures arrived at in this article may therefore be influenced by the motions of the Galaxy and the real R. A. of the Sun's apex may be nearer to 230° than 240°.

It would be interesting to know whether the proper motions of the south circumpolar stars present similar features. Those presented by the Carrington stars are at all events sufficiently striking to be worth calling attention to.

Dublin, Ireland.

ERRORS DISCOVERED IN THE KINETIC THEORY OF GASES, ETC.*

LUIGI D'AURIA.

FOR POPULAR ASTRONOMY.

The above paper was written for the purpose of proving the correctness of the theoretical ratio of the two specific heats, $\gamma = 2$, obtained as a result of a previous investigation published in POPULAR ASTRONOMY for April, 1907, under the title: "A new development of the kinetic theory of gases," by a new method quite independent of the expression for the pressure.

* A revision of the paper, "On some serious errors discovered in the kinetic theory of gases and in the application to it of Newton's second law of motion, etc.," published in POPULAR ASTRONOMY for June-July, 1907.

By an examination subsequently made of the paper in question I have found that in the expression (11) for the pressure, page 359, which reads $p = Qm\bar{v}$, I had no right to use the mean square speed $\bar{v}$ of the molecules in a given direction, although its use is in accordance with the expression $p = \rho\,\overline{v^2} = N\bar{v} \times m\bar{v}$, admitted generally in the kinetic theory, in which ρ is the density of the gas and N the number of molecules contained in unit volume of the gas, and we can see from this same expression that Q, the number of molecules crossing a section of unit area in unit time, is assumed to be equal to $N\bar{v}$. The product $m\bar{v}$ in the above expression is intended to represent the mean normal momentum of each of the Q molecules, but if we examine the problem more closely we find that this momentum should be expressed by mv in which I use v to represent the mean speed of the molecules in a given direction.

In the same paper I pointed out that Q should be independent of the directions of the motions of the molecules while crossing the section, and that instead of putting $Q = N\bar{v}$ we should put $Q = N\bar{u}$, in which $\bar{u}$ is the mean square speed of the molecules irrespective of direction. But here again I had no right to use $\bar{u}$, the proper speed in this expression being u, the mean speed irrespective of direction. Thus the equation (11) referred to above would become

$$p = Nu \times mv = \rho\, u\, v \qquad (1)$$

instead of the equation (15) page 360 which reads $p = \rho\,\bar{u}\,\bar{v}$ Assuming between v and u the the same relation which is generally assumed to exist between $\bar{v}$ and $\bar{u}$, viz: $\overline{v^2} = \frac{1}{3}\,\overline{u^2}$, we can put $v = u/\sqrt{3}$ and thus equation (1) becomes

$$p = \frac{\rho}{\sqrt{3}}\, u^2, \qquad (2)$$

instead of which, in the paper under revision, the equation(16) is given which reads $p = \rho/\sqrt{3} \,.\, \overline{u^2}$.

Now, in accordance with the well-known law of distribution of velocities found by Maxwell, the relation between u^2 and $\overline{u^2}$ is as follows:

$$u^2 = \frac{8}{3\pi}\,\overline{u^2}, \qquad (3)$$

and if we substitute this in (2) we find

$$p = \frac{8}{3\pi\sqrt{3}}\,\rho\,\overline{u^2} = 0.49\,.\rho\,\overline{u^2} \qquad (4)$$

Instead of this, in the same paper, the result arrived at was the equation (27) which reads $p = \frac{1}{2}\rho\,\overline{u^2}$, page 364, and which justifies the ratio $\gamma = 2$. In accordance with the new equation (4) we have $\gamma = 1.98$ which differs from the previous value only by one per cent. But the result $p = \frac{1}{2}\rho\,\overline{u^2}$ was obtained in spite of the fact that $\overline{v}$ and $\bar{u}$ had been erroneously used instead of v and u in the fundamental equation for the pressure, and by this error the value (4) of p is made, according to (3), $3\pi/8$ times larger. This was however neutralized by two other errors one of which is in the equation (17) giving $\overline{v} = \frac{2}{\pi}\,\bar{u}$ instead of $\overline{v} = \bar{u}/\sqrt{3}$ which is generally accepted and which is necessary in order to account for a gas being at rest as a whole. By this error the value (4) of p is unnecessarily multiplied by $2\sqrt{3}/\pi$. The remaining error is in my equation (26) page 364 which reads $t(\phi) = \frac{\pi}{4}mv$, and in which (ϕ) is the average value of the force ϕ involved during the impact of a molecule. This average value was taken with respect to the path of the force, but by a careful investigation of the problem of the pressure due to the bombardment of elastic molecules upon a surface I have found that the value of (ϕ) should be taken necessarily with respect to the duration of the application of the force, when the above equation will become $t(\phi) = mv$. Thus we see that by this last error the value (4) of p is unnecessarily multiplied by $\pi/4$. The combined effect of all the three errors upon this value of p amounts to its being multiplied by

$$\frac{3\pi}{3} \times \frac{2\sqrt{3}}{\pi} \times \frac{\pi}{4} = 1.00325,$$

which shows how nearly the above errors happened to compensate each other, leaving the result $p = \frac{1}{2}\rho\,\overline{u^2}$ practically the same. Indeed the difference which exists between this value and the new value (4) of p might be accounted for on the ground that the latter involves the relation (3) which may only apply approximately to the case of a gas.

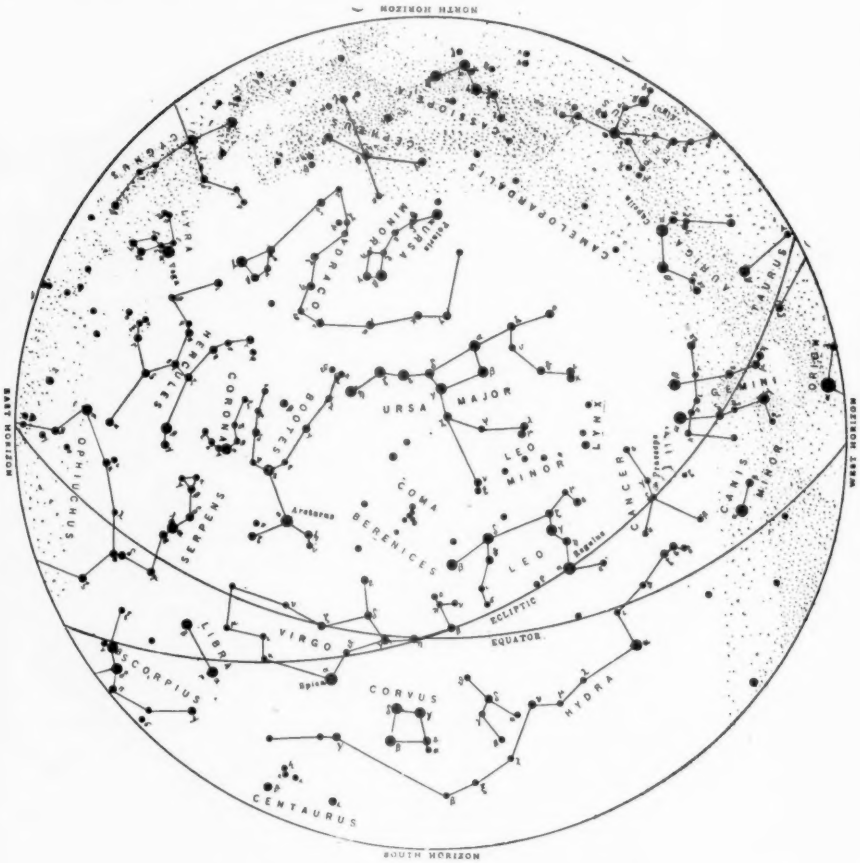
In a paper now in course of preparation the problems of the pressure and of the ratio of the two specific heats in the kinetic theory of gases are being considered more in detail, from a new point of view, and will shortly be submitted for publication.

Philadelphia Pa.

PLANET NOTES FOR MAY 1908.

H. C. WILSON.

Mercury will be at superior conjunction May 7 and so will not be in position favorable to study until near the end of the month, when it will be evening star seen low in the west soon after sunset.



THE CONSTELLATIONS AT 9:00 P. M., MAY 1, 1908.

Venus will attain her greatest brilliancy on May 29 and may be seen in broad daylight during probably all of this month. Of course one must know exactly where to look in order to see the planet in daylight. The best time for study of the planet with a telescope will be in the twilight just after the Sun has set. The phase will be crescent, decreasing from 0.477 on May 1 to 0.259 on May 31.

Mars may still be seen in the west after sunset, but is too low for useful study. The disk of the planet is now only about 4″ in diameter.

Jupiter is brilliant and well up toward the zenith at sunset. It may be studied for several hours each evening. The belts and satellites of Jupiter are well worth one's while to look at on these nights even with a small telescope.

Saturn is yet too close to the Sun for study but may be seen in the morning for a short time before sunrise.

Uranus may be seen in the morning, only with the aid of a telescope, in the constellation Sagittarius.

Neptune may be found with a telescope in the early evening, in Gemini. Its right ascension May 1 is $6^h\ 53^m\ 59^s$ and its declination $+\ 22°\ 5'$. On May 21 at 7^h A. M. Central Standard time Venus will be $4°\ 8'$ directly north of Neptune.

Occultations visible at Washington.

Date 1908	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration. h m
May 5	58 Geminorum	9.0	6 56	52	7 46	331	0 50
14	BD. 12° 4134	6.4	12 44	151	13 50	263	1 06
20	17 Capricorni	5.8	12 26	53	13 22	297	0 56

Phenomena of Jupiter's Satellites.

Central Standard Time, reckoning from noon.

	h	m					h	m			
May 1	7	55	III	Sh.	In.	May 10	10	45	II	Sh.	Eg.
	8	1	II	Oc.	Dis.		10	45	I	Sh.	Eg.
	10	44	I	Tr.	In.	11	7	57	I	Ec.	Re.
	11	38	III	Sh.	Eg.	15	7	31	IV	Tr.	Eg.
2	7	58	I	Oc.	Dis.	17	7	57	II	Tr.	In.
	11	33	I	Ec.	Re.		9	7	I	Tr.	In.
3	7	34	II	Tr.	Eg.		10	19	I	Sh.	In.
	8	7	II	Sh.	Eg.		10	26	II	Sh.	In
	8	50	I	Sh.	Eg.		10	54	II	Tr.	Eg.
7	10	43	IV	Ec.	Re.		11	27	I	Tr.	Eg.
8	6	50	III	Tr.	In.	18	9	53	I	Ec.	Re.
	10	31	III	Tr.	Eg.	19	7	8	I	Sh.	Eg.
	10	42	II	Oc.	Dis.		7	55	II	Ec.	Re.
	11	55	III	Sh.	In.		9	27	III	Ec	Re.
9	9	55	I	Oc.	Dis.	25	8	20	I	Oc.	Dis.
10	7	10	I	Tr.	In.	26	7	54	I	Tr.	Eg.
	7	49	II	Sh.	In.		8	52	III	Oc.	Re.
	8	12	II	Tr.	Eg.		9	3	I	Sh.	Eg.
	8	25	I	Sh.	In.		9	52	III	Ec.	Dis.
	9	30	II	Tr.	Eg.		10	30	II	Ec.	Re.

Note.—In., denotes ingress; Eg., denotes egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite: Sh., transit of the shadow.

COMET AND ASTEROID NOTES.

Ephemeris of Comet 1907 *d*.

(For Berlin Midnight, from *A. N.* 4234.)

1908	α 1908.0 h m s	δ 1908.0 ° ′	log *r*	log Δ	Mag.
April 2	14 42 42	−3 50.0	0.5399	0.4076	
4	40 43	3 37.5			
6	38 43	3 25.1	0.5458	0.4112	10.8
8	36 42	3 12.9			
10	34 39	3 0.9	0.5516	0.4157	
12	32 36	2 49.2			
14	30 32	2 37.7	0.5574	0.4209	10.9
16	28 29	2 26 6			
18	26 26	2 15.8	0.5631	0.4269	
20	24 25	2 5.4			
22	22 23	1 55.3	0.5687	0.4335	11.0
24	20 23	1 45.7			
26	18 25	1 36.5	0.5741	0.4409	
28	16 30	1 27 7			
30	14 36	1 19.4	0.5795	0.4490	11.1
May 2	12 44	1 11.6			
4	10 55	1 4.2	0.5848	0.4577	
6	9 11	0 57.4			
8	14 7 31	−0 51.2	0.5900	0.4670	11.3

New Planet or Satellite of Jupiter.—A cablegram received at this Observatory from Kiel states that a planet has been discovered by Melotte at Greenwich, positions of which are as follows:—

		h m s	° ′ ″
Jan. 27.5306	Gr. M. T.	R. A. 8 46 7.2	Dec. + 18 03 34
Feb. 28 4782		8 31 32.0	+ 19 16 13

The object has been observed on eight days and is possibly a satellite. It is visible in a large telescope.

A later telegram, from Professor Campbell states that the object was observed by Albrecht at Lick Observatory March 8.8486 Gr. m. t. in R. A. $8^h\ 28^m\ 33^s.2$, Dec. + 19° 39′ 11″, mean place for the beginning of this year. The object as observed visually by Aitken was of magnitude fifteen.

Astronomical Bulletin, No. 323,
Harvard College Observatory,
March 3, 1908.

VARIABLE STARS.

Variable 31.1907 Aurigæ.—A cablegram has been received at this Observatory from Kiel stating that Hartwig announces that Variable 31.1907 Aurigæ was of the ninth magnitude yesterday and is a U Geminorum type variable.

Note:—A chart of this region showing the position of the variable will be found in the *Astron. Nach.* Vol. 174, p. 363. E. C. P.

Astronomical Bulletin, No. 324,
Harvard College Observatory,
March 7, 1908.

The Variable 136.1907 Andromedæ.—In *A. N.* 4233 Mr. A. A. Nijland of Utrecht, concludes from an observation January 29, in connection with those previously published, that the period, of this star is 34.93 days and that the fractions ½, ⅓, and ¼ of this period are excluded by definite observations. Approximate elements are

Minimum = 2417935.51 + $34^d.93$ E.

The stationary minimum lasts at least 22.8 hours.

Elements of the Variable 139.1907 Ursæ Maj.—In *A. N.* 4231 Mr. S. Blažko of the Moscow Observatory announces that this star is of the δ Cephei type and gives the following elements:

Maximum = 1907 Oct. 5 $10^h.0$ Gr. m. t. + $11^h\ 14^m\ 24^s$ E.

The range of brightness is from $9^m.2$ to $9^m.9$ and the change lasts one and one-half hours.

Elements of the Variable 143.1907 Andromedæ.—In *A. N.* 4231 Mr. S. Blažko gives elements of this variable star determined from his own observations and photographs:

Minimum = 1907 Dec. 2, $9^h.0$ Gr. m. t. + $2^d\ 18^h\ 21^m.7$ E.

The star is of the Algol type and the period may possibly be only half of that given. The brightness ranges from $10^m.5$ to $11^m.3$, the loss and recovery of light occupying eight hours. (For position see P. A. Jan. 1907 p. 55).

Elements of the Variable 144.1907 Cassiopeiæ.—In *A. N.* 4231 Mr. S. Blažko gives the following elements of the variable star 144.1907 Cassiopeiae, determined from five minima in the years 1896 to 1907:

Maximum = 1907 Dec. 1 $11^h.5$ Gr. m. t. + $4^d\ 1^h\ 42^m.4$ E

= J. D. 2417911.48 + $4^d.0711$ E.

The star is of the δ Cephei type and the brightness ranges from $9^m.3$ to $9^m.9$ (See P. A. Jan. 1908 p. 55).

Two New Variables 3 and 4.1908.—These were discovered by Mme. L. Ceraski upon the Moscow photographs and are announced in *A. N.* 4234. Their positions are:

	α 1855	δ 1855	α 1900	δ 1900
	h m s	° ′ ″	h m s	° ′ ″
3.1908 Aurigae	5 4 51.10	+49 22 23.2	5 8 17.65	+49 25 51.7
4.1908 Aurigae	4 47 12.3	+48 19.0	4 50 34.9	+48 23.6

No. 3 is BD + 49°.1331 ($8^m.9$) and from a study of twenty-four plates obtained in the years 1899 to 1907, it appears that the magnitude varies between 8.6 and 9.3. The period is probably short.

No. 4 is BD. + 48°1187 ($9^m.5$). Judging from eighteen photographs obtained in 1899-1907, the brightness varies from 10^m to about 12^m. The period is unknown.

Elements of the Variable RY Aurigæ.—In *A. N.* 4231 Mr. S. Blažko gives elements of this variable star as follows:

Minimum = 1907 Oct. 5 $13^h.5$ Gr. m. t. + $2^d\ 17^h\ 24^m.3$ E

The star is of the Algol type and the change of light lasts eight hours, the range being about a magnitude, from 11^m to 12^m (For position see P. A. Feb. p. 120).

Elements of Three Algol Stars.—In *A. N.* 4232 Mr. S. Enebo of Dombaas, Norway gives approximate elements of the variable stars as follows:

RY(27.1907) Aurigæ	Minimum	= 2417887.24 Gr. m. t.	+ 2^d.728 E
49.1907 Geminorum	"	= 2417884.50 "	+ 12.21 E
143.1907 Andromedæ	"	= 2417912.426 "	+ 2.764 E

Elements of Y Camelopardalis.—In *A. N.* 4232 Mr. S. Blažko gives the following elements of this variable and suggests that possibly the period is not constant:

Minimum = 2416306.3887 Gr. m. t. + 3^d.305550 E.

Sixteen New Variable Stars.—Circular No. 134 of the Harvard College Observatory contains a list of sixteen new variables, discovered by Miss Cannon, in the regions of the Harvard Map Nos. 37 and 46. These have been given the numbers 183 to 198.1907 by the Variable Star Committee of the Astronomische Gesellschaft.

No.	Constellation	DM	R.A. 1900 h m s	Dec. 100 ° ′	Mag.
183.1907	Tucanæ	—	0 10 17	−60 46.8	9.4 — 10.2
184.1907	Phœnicis	−50° 118	0 30 19	−50 45.2	9.5 −<11
185.1907	Tucanæ	−72 69	0 48 10	−72 32.6	8.8 — 10.3
186.1907	Tucanæ	—	0 54 09	−63 55.9	9.0 — 10.1
187.1907	Cœli	−33 2018	4 53 12	−33 18.4	9.7 — 10.5
188.1906	Columbæ	−30 2883	6 06 25	−30 43.2	10.4 −<15
189.1907	Canis Maj.	−26 2912	6 14 49	−26 07.9	9.8 −<12
190.1907	Columbæ	—	6 24 35	−40 02.2	9.3 −<11.5
191.1907	Columbæ	−35 2972	6 29 44	−35 14.0	9.8 — 10.4
192.1907	Puppis	−42 2682	6 39 21	−42 16.6	9.1 −<11.5
193.1907	Canis Maj.	—	6 39 44	−31 41.2	10.0 −<12
194.1907	Canis Maj.	−23 4628	6 52 36	−23 50.4	8.9 — 10.1
195.1907	Canis Maj.	−25 3986	7 00 03	−25 38.9	9.5 — 10.2
196.1907	Indi	−70 2860	21 27 41	−70 46.6	9.0 — 10.0
197.1907	Phœnicis	−46 14688	23 27 01	−46 32.2	8.5 −<12
198.1907	Phœnicis	−52 12232	23 51 53	−52 46.9	10.1 — 11.0

Of these Nos. 183, 185, 186, 187, 191, 196 appear to be of short period, 185 and 191 being of the Algol type.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei		RZ Cassiop.		RZ Cassiop.		RX Cephei		RW Geminorum	
d	h	d	h	d	h	d	h	d	h
May 1	18	May 1	22	May 17	11	May 30	20	May 25	18
4	6	3	3	18	15	RS Cephei		28	15
6	18	4	7	19	20	May 10	0	31	12
9	6	5	12	21	1	22	10	RU Monoc.	
11	17	6	17	22	5	RW Geminorum		May 1	12
14	5	7	21	23	10	May 2	20	2	10
16	17	9	2	24	15	5	17	3	7
19	5	10	7	25	19	8	13	4	5
21	17	11	11	27	0	11	10	5	2
24	5	12	16	28	5	14	7	6	0
26	16	13	21	29	9	17	4	6	21
29	4	15	1	20	14	20	1	7	19
31	16	16	6	31	19	22	21	8	16

Minima of Variable Stars of the Algol Type.—Continued.

RU Monoc.

	d	h
May	9	14
	10	11
	11	9
	12	6
	13	4
	14	1
	14	23
	15	20
	16	18
	17	15
	18	13
	19	10
	20	8
	21	5
	22	3
	23	0
	23	22
	24	19
	25	17
	26	14
	27	12
	28	10
	29	7
	30	5
	31	2

R Canis Maj.

	d	h
May	1	22
	3	1
	4	4
	5	8
	6	11
	7	14
	8	17
	9	21
	11	0
	12	3
	13	6
	14	10
	15	13
	16	16
	17	19
	18	23
	20	2
	21	5
	22	9
	23	12
	24	15
	25	18
	26	22
	28	1
	29	4
	30	7
	31	11

Y Camelop.

	d	h
May	2	22
	6	6
	9	13
	12	20
	16	4
	19	11

Y Camelop.

	d	h
May	22	18
	26	2
	29	9

RR Puppis

	d	h
May	1	4
	7	14
	14	0
	20	11
	26	21

V Puppis

	d	h
May	1	23
	3	10
	4	21
	6	8
	7	19
	9	6
	10	17
	12	4
	13	15
	15	2
	16	12
	17	23
	19	10
	20	21
	22	8
	23	19
	25	6
	26	17
	28	4
	29	15
	31	2

S Cancri

	d	h
May	1	9
	10	21
	20	9
	29	20

S Velorum

	d	h
May	3	2
	9	0
	14	23
	20	21
	26	20

RR Velorum

	d	h
May	2	13
	4	10
	6	6
	8	3
	9	23
	11	20
	13	16
	15	13
	17	9
	19	6
	21	2
	22	23
	24	19
	26	16
	28	12
	30	9

SS Cancri

	d	h
May	3	3
	6	11
	9	18
	13	1
	16	8
	19	15
	22	23
	26	6
	29	13

Z Draconis

	d	h
May	2	5
	3	13
	4	22
	6	7
	7	15
	9	0
	10	8
	11	17
	13	1
	14	10
	15	19
	17	3
	18	12
	19	21
	21	5
	22	14
	23	22
	25	7
	26	15
	28	0
	29	8
	30	17

RZ Centauri

	d	h
May	1	19
	2	18
	3	16
	4	15
	5	13
	6	12
	7	10
	8	9
	9	7
	10	6
	11	4
	12	3
	13	1
	14	0
	14	22
	15	21
	16	19
	17	18
	18	16
	19	15
	20	13
	21	12
	22	10
	23	9
	24	7
	25	6
	26	4

RZ Centauri

	d	h
May	27	3
	28	1
	29	0
	29	22
	30	21
	31	19

SS Centauri

	d	h
May	1	14
	4	2
	6	13
	9	1
	11	12
	14	0
	16	11
	18	23
	21	10
	23	22
	26	9
	28	21
	31	8

δ Libræ

	d	h
May	3	0
	5	8
	7	15
	9	23
	12	7
	14	15
	16	23
	19	7
	21	15
	23	22
	26	6
	28	14
	30	22

U Coronæ

	d	h
May	1	6
	4	17
	8	4
	11	15
	15	1
	18	12
	21	23
	25	10
	28	21

R Aræ

	d	h
May	3	8
	7	19
	12	5
	16	15
	21	1
	25	11
	29	22

U Ophiuchi

	d	h
May	1	16
	2	12
	3	8
	4	4
	5	0
	5	20
	6	17

U Ophiuchi

	d	h
May	7	13
	8	9
	9	5
	10	1
	10	21
	11	17
	12	14
	13	10
	14	6
	15	2
	15	22
	16	18
	17	14
	18	10
	19	7
	20	23
	20	3
	21	19
	22	15
	23	11
	24	7
	25	3
	26	0
	26	20
	27	16
	28	12
	29	8
	30	4
	31	0
	31	20

Z Herculis

	d	h
May	3	8
	5	5
	7	8
	9	5
	11	7
	13	4
	15	7
	17	4
	19	7
	21	4
	23	7
	25	4
	27	7
	29	4
	30	7

RS Sagittarii

	d	h
May	2	11
	4	21
	7	7
	9	17
	12	3
	14	13
	16	23
	19	9
	21	19
	24	4
	26	14
	29	0
	31	10

Minima of Variable Stars of the Algol Type.—Continued.

V Serpentis

	d	h
May	1	2
	4	13
	8	0
	11	11
	14	22
	18	9
	21	20
	25	7
	28	17

RZ Herculis

	d	h
May	1	6
	2	9
	3	11
	4	14
	5	16
	6	19
	7	21
	9	0
	10	2
	11	4
	12	7
	13	9
	14	12
	15	14
	16	17
	17	19
	18	22
	20	0
	21	2
	22	5
	23	7
	24	10
	25	12
	26	15
	27	17
	28	20
	29	22
	31	0

RX Herculis

	d	h
May	1	5
	2	2
	3	0
	3	21
	4	18
	5	16
	6	13
	7	10
	8	8
	9	5
	10	2
	11	0

RX Herculis

	d	h
May	11	21
	12	18
	13	16
	14	13
	15	11
	16	8
	17	5
	18	3
	19	0
	19	21
	20	19
	21	16
	22	13
	23	11
	24	8
	25	5
	26	3
	27	0
	27	21
	28	19
	29	16
	30	13
	31	11

SX Sagittarii

	d	h
May	2	16
	4	18
	6	20
	8	21
	10	23
	13	1
	15	3
	17	5
	19	7
	21	8
	23	10
	25	12
	27	14
	29	16
	31	18

RR Draconis

	d	h
May	3	17
	6	12
	9	8
	12	4
	15	0
	17	20
	20	16
	23	12
	26	8
	29	4

U Scuti

	d	h
May	1	21
	2	20
	3	19
	4	18
	5	17
	6	16
	7	15
	8	14
	9	12
	10	11
	11	10
	12	9
	13	8
	14	7
	15	6
	16	5
	17	4
	18	3
	19	2
	20	1
	21	0
	21	22
	22	21
	23	20
	24	19
	25	18
	26	17
	27	16
	28	15
	29	14
	30	13
	31	12

RX Draconis

	d	h
May	1	1
	2	22
	4	19
	6	17
	8	14
	10	12
	12	9
	14	7
	16	4
	18	2
	19	23
	21	21
	23	18
	25	16
	27	13
	29	10
	31	8

RV Lyræ

	d	h
May	3	22
	7	13
	11	3
	14	17
	18	8
	21	22
	25	13
	29	3

U Sagittæ

	d	h
May	1	11
	4	20
	8	5
	11	14
	15	0
	18	9
	21	18
	24	3
	28	12
	31	21

SY Cygni

	d	h
May	6	7
	12	7
	18	8
	24	8
	30	8

WW Cygni

	d	h
May	4	5
	7	12
	10	20
	14	4
	17	11
	20	19
	24	3
	27	10
	30	18

SW Cygni

	d	h
May	3	20
	8	10
	12	23
	17	13
	22	3
	26	17
	31	6

VW Cygni

	d	h
May	6	11
	14	21
	23	7
	31	18

UW Cygni

	d	h
May	2	19
	6	6
	9	17
	13	3
	16	14
	20	1
	23	12
	26	23
	30	10

W Delphini

	d	h
May	1	8
	6	4
	10	23
	15	18
	20	14
	25	9
	30	5

RR Delphini

	d	h
May	1	20
	6	10
	11	0
	15	15
	20	5
	24	20
	29	10

VV Cygni

	d	h
May	1	18
	3	5
	4	17
	6	4
	7	16
	9	3
	10	15
	12	2
	13	14
	15	1
	16	13
	18	0
	19	11
	20	23
	22	10
	23	22
	25	9
	26	21
	28	8
	29	20
	31	7

UZ Cygni

	d	h
May	29	12

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

Maxima of Variable Stars of Short Period not of the Algol Type.

RW Cassiop.

	d	h
	(−5	19)
May	6	22
	21	17

RX Aurigæ

	(−4	0)
May	9	9
	21	0

Y Aurigæ

	(−0	18)
May	2	1
	5	22
	9	19
	13	15
	17	12
	21	8
	25	5
	29	2

T Monoc.

	(−7	23)
May	26	11

W Geminorum

	(−2	22)
May	1	11
	9	9
	17	7
	25	5

ζ Geminorum

	(−5	0)
May	1	1
	11	5
	21	8
	31	12

RU Camelop.

	(−9	12)
May	3	10
	25	16

V Carinæ

	(−2	4)
May	4	9
	11	1
	17	18
	24	11
	31	3

T Velorum

	(−1	10)
May	4	2
	8	18
	13	9
	18	0
	22	16
	27	7
	31	22

W Carinæ

	(−1	0)
May	1	19
	6	4
	10	13
	14	22
	19	6
	23	15
	28	0

S Muscæ

	d	h
	(−3	11)
May	9	3
	18	19
	28	11

T Crucis

	(−2	2)
May	2	13
	9	7
	16	0
	22	18
	29	11

R Crucis

	(−1	10)
May	5	23
	11	19
	17	15
	23	10
	29	6

S Crucis

	(−1	12)
May	3	23
	8	16
	13	8
	18	1
	22	17
	27	10

W Virginis

	(−8	5)
May	17	13

V Centauri

	(−1	11)
May	1	16
	7	4
	12	16
	18	4
	23	15
	29	3

R Triang. Austr.

	(−1	0)
May	3	9
	6	18
	10	3
	13	13
	16	22
	20	7
	23	17
	27	2
	30	11

S Triang. Austr.

	(−2	2)
May	2	20
	9	3
	15	11
	21	19
	28	3

S Normæ

	(−4	10)
May	10	6
	20	0
	29	18

RV Scorpii

	d	h
	(−1	10)
May	1	5
	7	6
	13	8
	19	9
	25	11
	31	12

RV Ophiuchi Minimum.

May	2	21
	6	13
	10	6
	13	22
	17	15
	21	7
	25	0
	28	16

X Sagittarii

	(−2	22)
May	1	1
	8	2
	15	2
	22	2
	29	2

Y Ophiuchi

	(−6	5)
May	14	9
	31	12

W Sagittarii

	(−3	0)
May	7	1
	14	15
	22	5
	29	19

Y Sagittarii

	(−2	2)
May	5	8
	11	3
	16	21
	22	16
	28	10

U Sagittarii

	(−2	23)
May	2	16
	9	10
	16	4
	22	22
	29	16

β Lyræ

	(−3	7)
	(−3	2)
May	2	23
	10	5
	16	21
	23	3
	29	19

κ Pavonis

	(−1	7)
May	4	0
	13	3
	22	5
	31	7

U Aquilæ

	d	h
	(−2	4)
May	3	3
	10	4
	17	4
	24	5
	31	5

U Vulpeculæ

	(−2	3)
May	8	14
	16	14
	24	13

SU Cygni

	(−1	7)
May	1	20
	5	16
	9	12
	13	9
	17	5
	21	1
	24	21
	28	18

η Aquilae

	(−2	6)
May	1	18
	8	23
	16	3
	23	7
	30	11

S Sagittae

	(−3	10)
May	8	20
	17	5
	25	14

X Vulpeculæ

	(−2	1)
May	2	10
	8	17
	15	1
	28	9
	27	16

V Vulpeculae Minimum

May	12

X Cygni

	(−6	19)
May	10	8
	26	17

T Vulpeculae

	(−1	10)
May	2	2
	6	12
	10	23
	15	9
	19	20
	24	6
	28	17

WZ Cygni

	d	h
	Minimum	
May	1	10
	2	4
	3	18
	4	23
	6	3
	7	7
	8	11
	9	15
	10	19
	11	23
	13	3
	14	7
	15	11
	16	15
	17	19
	18	23
	20	3
	21	7
	22	11
	23	15
	24	19
	25	23
	27	4
	28	8
	29	12
	30	16
	31	20

TX Cygni

May	26	11

VY Cygni

	(−2	14)
May	6	13
	14	10
	22	6
	30	3

VZ Cygni

	(−3	6)
	(−2	12)
May	5	0
	9	17
	14	17
	19	10
	24	10
	29	4

δ Cephei

	(−1	10)
May	4	9
	9	18
	15	3
	20	12
	25	20
	31	5

V Lacertae

	(−0	17)
May	5	3
	10	2
	15	2
	20	2
	25	1
	30	1

Maxima of Variable Stars of Short Period not of the Algol Type

Continued.

X Lacertae			X Lacertae			RS Cassiop.			RY Cassiop.			Y Lacertae		
	d	h		d	h		d	h		d	h		d	h
	Minimum						(−1	19)		(−7	10)			
May	3	14	May	19	22	May	7	5	May	9	21	May	6	22
	9	1		25	9		13	12		22	0		11	6
	14	12		30	19		19	19	Y Lacertae				15	14
							26	3		(−1	10)		19	21
									May	2	15		24	5
													28	12

Approximate Magnitudes of Variable Stars on Mar. 1, 1908.

Name.	h	R. A. 1900. m	Decl. 1900. ° ′	Magn.	Name.	h	R.A. 1900. m	Decl. 1900. ° ′	Magn.
X Androm.	0	10.8	+46 27	<13.2	R Orionis	4	53.6	+ 7 59	9.4
T Androm.		17.2	+26 26	8.2*d*	R Leporis		55.0	−14 57	11.0
T Cassiop.		17.8	+55 14	11.4*d*	V Orionis	5	0.8	+ 3 58	12.8*d*
R Androm.		18.8	+38 1	13.9*d*	T Leporis		0.6	−22 2	11.0
S Ceti		19.0	− 9 53	7.8 *i*	R Aurigae		9.2	+53 28	10.5*d*
Y Cephei		31.3	+79 48	11.5 *i*	S Aurigae		20.5	+34 4	10.0
U Cassiop.		40.8	+47 43	9.1 *i*	W Aurigae		20.1	+36 49	11.0*d*
V Androm.		44.6	+35 6	10.0 *i*	S Orionis		24.1	− 4 46	12.4*d*
RW Androm.		41.9	+32 8	12.0 *i*	T Orionis		30.9	− 5 32	9.8
RR Androm.		45.9	+33 50	<13	S Camelop.		30.2	+68 45	8.8 *i*
W Cassiop.	0	49.0	+58 1	10.2	RR Tauri		33.3	+26 19	11.6
RX Androm.		58.9	+40 46	12.5 *i*	U Aurigae		35.6	+31 59	12.6*d*
U Androm.	1	9.8	+40 11	12.6 *i*	Z Tauri		46.7	+15 46	<12.6
S Piscium		12.4	+ 8 24	10.6 *i*	V Camelop.		49.4	+74 30	<13
S Cassiop.		12.3	+72 5	13.0 *i*	U Orionis		49.9	+20 10	10.4 *i*
U Piscium		17.7	+12 21	13.6*d*	Z Aurigæ		53.6	+53 18	11.4*d*
R Piscium		25.5	+ 2 22	12.6 *i*	X Aurigae	6	4.4	+50 15	<13.5
RU Androm.		32.8	+38 10	13.5*d*	V Aurigae		16.5	+47 45	9.0
Y Androm.		33.7	+38 50	13.0*d*	V Monoc.		17.7	− 2 9	11.8*d*
X Cassiop.		49.8	+58 46	9.4 *i*	S Lyncis		35.9	+58 0	<13
U Persei		53.0	+54 20	8.2	X Gemin.		40.7	+30 23	12.0*d*
S Arietis		59.3	+12 3	12.0	W Monoc.		47.5	− 7 2	10.4*d*
R Arietis	2	10.4	+24 35	10.0*d*	Y Monoc.		51.3	+11 22	12.8 *i*
W Androm.		11.2	+43 50	<13	X Monoc.		52.4	− 8 56	7.8
Z Cephei		12.8	+81 13	13.0 *i*	R Lyncis		53.0	+55 28	10.8*d*
o Ceti		14.3	− 3 26	7.2*d*	RS Gemin.		55.2	+30 40	11.0
S Persei		15.7	+58 8	8.6	R Gemin.	7	1.3	+22 52	13.0*d*
R Ceti		20.9	− 0 38	9.6 *i*	V Can. Min.		1.5	+ 9 2	<12.5
U Ceti		28.9	−13 35	9.0*d*	R Can. Min.		3.2	+10 11	8.4 *i*
RR Cephei		30.4	+80 42	13.3	RR Monoc.		12.4	+ 1 17	13.0*d*
R Trianguli		31.0	+33 50	7.0 *i*	V Gemin.		17.6	+13 17	9.6*d*
T Arietis		42.8	+17 6	8.0	S Can Min.		27.3	+ 8 32	12.8*d*
W Persei		43.2	+56 34	9.2	T Can. Min.		28.4	+11 58	12.8
U Persei	3	5.5	+14 25	9.0*d*	Z Puppis		28.3	−20 27	<12.8
X Ceti		14.3	− 1 26	8.6 *i*	U Can. Min.		35.9	+ 8 37	9.2 *i*
Y Persei		20.9	+43 50	9.0	S Gemin.		37.0	+23 41	13.2 *i*
U Persei		23.7	+35 20	12.6*d*	T Gemin.		43.3	+23 59	9.6*d*
Nov. Per. 2		24.4	+43 34	13.2	U Puppis		56.1	−12 34	13.2*d*
T Tauri	4	16.2	+19 18	11.6	R Cancri	8	11.0	+12 2	11.0*d*
R Tauri		22.8	+ 9 56	<12.6	V Cancri		16.0	+17 36	10.8*d*
W Tauri		22.2	+15 49	9.2*d*	RT Hydrae		24.7	− 5 59	8.4 *i*
S Tauri		23.7	+ 9 44	10.8 *i*	U Cancri		30.0	+19 14	12.8
T Camelop.		30.4	+65 57	8.0	X Urs. Maj.		33.7	+50 30	10.5 *i*
RX Tauri		32.8	+ 8 9	<13	S Hydrae		48.4	+ 3 27	8.6
X Camelop.		32.6	+74 56	12.0	T Hydrae		50.8	− 8 46	8.2
V Tauri		46.2	+17 22	9.8	T Cancri		51.0	+20 14	9.4

Approximate Magnitudes of Variable Stars on Mar. 1, 1908—Con.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900 h	m	Decl. 1900 °	′	Magn.
S Pyxidis	9	0.7	−24	41	10.0*d*	X Coronae	15	45.2	+36	35	9.0
W Cancri		4.0	+25	39	12.4*d*	R Serpentis		46.1	+15	26	13.2*d*
X Hydrae		30.7	−14	15	10.6*d*	V Coronae		46.0	+39	52	8.3 *i*
Y Draconis		31.1	+78	18	<12.8	R Librae		47.9	−15	56	<12.6
R Leo. Min.		39.6	+34	58	9.8*d*	RR Librae		50.6	−18	1	9.0*d*
RR Hydrae		40.4	−23	34	12.8	— Coronae		5.2	+29		11.7 *i*
R Leonis		42.2	+11	54	7.0*d*	RZ Scorpii		58.6	−23	50	9.6 *i*
Y Hydrae		46.4	−22	33	6.5	Z Scorpii	16	0.1	−21	28	10.5
V Leonis		54.5	+21	44	13.5	R Herculis		1.7	+18	38	11.0 *i*
R Urs. Maj.	10	37.6	+69	18	12.3*d*	RR Herculis		1.5	+50	46	9.2
V Hydrae		46.8	−20	43	11.0 *i*	U Serpentis		2.5	+10	12	13.0
S Leonis	11	5.7	+ 6	0	10.2	X Scorpii		2.7	−21	16	10.5
R Comae		59.1	+19	20	13.8*d*	W Scorpii		5.9	−19	53	<13
T Virginis	12	9.5	−52	9	13.0	RX Scorpii		5.9	−24	38	11.4
SS Virginis		20.1	+ 1	19	7.8	RU Herculis		6.0	+25	20	12.6
R Corvi		14.4	−18	42	10.5 *i*	R Scorpii		11.7	−22	42	<12.9
T Can. Ven.		25.2	+32	3	11.6 *i*	S Scorpii		11.7	−22	39	11.5
Y Virginis		28.7	− 3	52	11.6 *i*	V Ophiuchi		21.2	−12	12	8.5
T Urs. Maj.		31.8	+60	2	9.7*d*	U Herculis		21.4	+19	7	13.0
R Virginis		34.4	+ 7	32	8.6*d*	Y Scorpii		23.8	−19	13	<12.8
RS Urs. Maj.		34.4	+59	2	8.5 *i*	SS Herculis		28.0	+ 7	3	9.5 *i*
S Urs. Maj.		39.6	+61	38	8.0	S Ophiuchi		28.5	−16	57	11.0*d*
RU Virginis		42.2	+ 4	42	10.0	T Ophiuchi		28.0	−15	55	9.8 *i*
U Virginis		46.0	+ 6	6	<13	W Herculis		31.7	+37	32	11.8*d*
RT Virginis		57.6	+ 5	43	8.4	R Draconis		32.4	+66	58	8.0 *i*
RV Virginis	13	2.8	−12	38	<12.5	RR Ophiuchi		43.2	−19	17	9.6
V Virginis		22.6	− 2	39	8.8	S Herculis		47.4	+15	7	9.2
R Hydrae		24.2	−22	46	8.6*d*	RV Herculis		56.8	+31	22	12.2
S Virginis		27.8	− 6	41	9.6	R Ophiuchi	17	2.0	−15	58	10.2
T Urs.Min.		32.6	+73	56	1.2*d*	U Lyrae	19	16.6	+37	42	12.0*d*
R Can. Ven.		44.6	+40	2	8.8*d*	TY Cygni		29.8	+28	6	<13
RR Virginis		59 6	− 8	43	13.2	R Cygni		34.1	+49	58	13.6
Z Bootis	14	1.7	+13	59	12.6 *i*	RT Cygni		40.8	+48	32	12.0d
Z Virginis		5.0	−12	50	10.9 *i*	χ Cygni		46.7	+32	40	9.2 *i*
U Urs. Min.		15.1	+67	15	11.0*d*	Z Cygni		58.6	+49	46	9.0*d*
S Bootis		19.5	+54	16	9.0 *i*	U Cygni	20	16.5	+47	35	7.0
RS Virginis		22.3	+ 5	8	10.7 *i*	V Cygni		38.1	+47	47	13.0*d*
V Bootis		25.7	+39	18	8.2*d*	X Cephei	21	3.6	+82	40	<13.2
R Camelop.		25.1	+84	17	8.4 *i*	T Cephei		8.2	+68	5	9.0 *i*
R Bootis		32.8	+27	10	10.3*d*	S Cephei		36.5	+78	10	7.6 *i*
V Librae		34.8	−17	14	10.6 *i*	RV Pegasi	22	21.0	+29	58	13.5*d*
U Bootis		49.7	+18	6	12.0*d*	S Lacertae		24.6	+39	48	13.2*d*
RT Librae	15	0.8	−18	21	12.8 *i*	R Lacertae		38.8	+41	51	13.6
T Librae		5.9	−19	38	12.5 *i*	RW Pegasi		59.2	+14	46	8.4*d*
Y Librae		6.4	− 5	38	11.2 *i*	R Pegasi	23	1.6	+10	0	13.0
S Librae		15.6	−20	2	8.8*d*	V Cassiop.		7.4	+59	8	12.2 *i*
S Serpentis		17.0	+14	40	12.9 *i*	W Pegasi		14.8	+25	44	10.2*d*
S Coronae		17.3	+31	44	8.8 *i*	S Pegasi		15.5	+ 8	22	13.2
RS Librae		18.5	−22	33	9.3*d*	Z Androm.		28.8	+48	16	11.3
RU Librae		27.7	−14	59	13.0 *i*	— Androm.		33.8	+35	13	9.0
X Librae		30.4	−20	50	11.6 *i*	Z Cassiop.		39.7	+56	2	<12.8
S Urs.Min.		33.4	+78	58	10.4 *i*	RR Cassiop.		50.7	+53	8	<12.5
U Librae		36.2	−20	52	11.1 *i*	R Cassiop.		53.3	+50	50	11.8*d*
Z Librae		40.7	−20	49	<13	Z Pegasi		55.0	+25	21	8.6*d*
R Coronae		44.4	+28	28	6.2	Y Cassiop.		58.2	+55	7	12.0 *i*

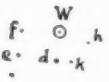
The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whitin, Mt. Holyoke, and Harvard Observatories.

Variable Star Note.

W Cassiopeiæ.—In the February number of POPULAR ASTRONOMY a few typographical errors appeared in the record of this variable, and to hinder any misleading effect, a corrected copy is inserted in this issue.

1905 May 27 Between a and c; brighter than d. Morning very clear.
June 26 Between a and c.
July 6 The same.
Sept 17, 24 Equal to h; less than d.
Oct. 15 Between d and h.
Oct. 23, 26 Equal to h: less than e or f.
Nov. 3 The same.
Nov. 14, 20, 30 Between h and k.
Dec. 3 Dimmer than h or k.



VICINITY OF W CASSIOPELE.

1906 Aug. 12, 19 Equal to c.
Sept. 16, 26 Equal to d; less than c.
Oct. 3, 6, 12 Equal to d; brighter than h.
Nov. 4, 20 Less than e or f; equal to h.
1907 Aug. 8, 25 Brighter than d or c, less than a.
Sept. 1, 4, 12 The same.
Sept. 15 Equal to a.
Sept. 23 Less than a, brighter than c.
Sept. 29 Slightly brighter than c or d. Night clear.
Oct. 2, 7, 14 Equals d; brighter than e.
Oct. 28, 30 Less than d, equals e.
Nov. 2, 7, 21 The same.
Nov. 24 Less than e.

ROSE O'HALLORAN.

San Francisco,
February 20, 1908

GENERAL NOTES.

Occultation of Zeta Tauri. On February 11th., I observed with my 5-inch telescope, power 136 diameters, the occultation of ζ Tauri, and saw what I have never before observed, viz. a momentary fading of light before extinction. The star was bright and well-defined, but so much daylight remained that I could not see the dark limb of the Moon, so I did not know at what

moment to expect occultation, but looked steadily at the star. While so doing, I perceived for an instant that the star was fading, and then it was gone. The time of fading was less than a second but it was long enough to make me conscious that the star *was being* occulted. The difference between this and all other occultations which I have ever seen was like the difference between the turning off a gas light and an electric light. In the one case you know the light *is going out*, in the other, it is *instantly gone*. The dimming may have been due to something in our own atmosphere. If not, I am inclined to believe that the occultation occurred at a point on the Moon's limb where something seemed to obscure the light of the star. Whatever may have been the cause, I am certain that there was the momentary fading of the star's light.

TILTON C. H. BOUTON.

Henniker, N. H.
February 13, 1908.

The Paris Observatory. An illustrated article, the leader in the March number of the *Bulletin* of the Astronomical Society of France gives a brief history of that old, and very famous institution. The cuts showing the building in the process of completion, the medal commemorative of the foundation of the Observatory in 1667, the antique instruments then in use, as compared with the modern condition and equipment of the same Observatory, makes very interesting reading especially when presented by such a gifted writer as Camille Flammarion. He knows well about the history of this great Observatory, for he has had much to do with the ecent parts of it.

Why there are no Mountains on Mars. The study of the planet Mars furnishes satisfactory evidence that it has no mountains at all comparable to those found upon the Earth, and the question naturally arises why were mountains not formed on Mars, as well as on our own planet? In three memoirs recently communicated to the American Philosophical Society held at Philadelphia, two of which have been published in the Proceedings for 1906 and 1907 respectively, the writer has shown that the mountains have been formed by the expulsion of lava from beneath the sea, owing to the accumulation of steam beneath the Earth's crust, by the secular leakage of the ocean bottoms. The effect naturally is greatest near deep seas, because of the great fluid pressure on the bed of the ocean, and it is around the margins of such oceans that the great mountain chains are formed.

If then we had a desert like Mars, with no large or deep seas, there should be no mountains on it because appreciable leakage would not take place, as upon the Earth. And as mountain formation would not be in progress, the planet would be undisturbed by earthquakes.

It is true that at present the Moon has mountains without any water, but this is due to the fact that the water formerly upon the Moon has escaped into space, owing to the feeble attraction of our satellite, which is unable to retain the molecule of water vapor. The quantity of water once upon the Moon may have been quite large, and the mountain building on our satellite dates from this earlier stage of development. In the case of Mars, however, the planet probably is able to retain most of its water vapor, but the bodies of water are so small that the effect on mountain building is insensible.

T. J. J. SEE.

Astr. Nachr. No. 4232.

Theoretical Parallax of the Great Nebula in Andromeda. If the linear semi-diameter (Δ) and the angular semi-diameter (s) of any nebula, be known, its distance (δ) from the Earth, and its parallax (π), expressed in seconds of arc, are determinable through the following equations: $\delta = \frac{\Delta}{\tan s}$; (1), and, $\pi = \frac{\omega}{\delta}$; (2) in which ω represents the number of seconds in an arc equal in length to the radius of a circle—its value being 206,264.81.

In the February number of POPULAR ASTRONOMY I described my theoretical method of determining the radius of the primitive nebula whence the Sun and the planetary—and other—members of the solar system have been evolved, this nebulous mass being considered as a *sphere* the radius whereof, according to my determination therein set forth, is 12,850 times the mean distance of the Earth from the Sun.

Regarding this nebula as really *oblate*, or oval,—like the great nebula in Andromeda—I have found its longer semi-axis to be three times the aforesaid value of the *spherical* radius, or 38,550 *astronomical units*, and this is taken as the value of Δ, while from the reproduction of the superb *Ritchey* photograph, in the March number P. A. the angular semi-diameter (s) is found to be, very approximately 1°, so that, as determined through equation (1) the value of δ is 2,208,520 times the Earth's mean semi-distance from the Sun—the great nebula in the constellation Andromeda being therefore, 205,172,000,000,000 miles distant from the Earth.

The above stated value of δ, and that of ω as aforesaid, being substituted in equation (2), there results as the theoretical value of the parallax (π) of the Andromeda nebula, 0″.094. Now, the parallax of that nebula, as found by Carl Bohlin of Stockholm, Sweden—according to a statement published in the January number (151) of P. A.—is 0″.17, this being a mean of three values, viz. 0.20, 0″.19 and 0″.08 determined by him, whence it appears that my theoretical value, set forth above, is in close agreement with the smallest of those determined by Mr. Bohlin. It seems to me that instrumental determinations of a parallax as small as this are most liable to give values in *excess* of the *true* one, and that the smallest of Mr. Bohlin's three results is, most probably the nearest to the true value. In fact, if we take one-tenth of a second of arc as the parallax of the great nebula in Andromeda, this figure will probably be as close an approximation to the true value as can be made under present conditions. This nebula, by reason of its well-defined, spiral, conformation as well as its spectroscopic aspect, is, evidently, in an advanced stage of development, and, in every respect, quite similar to the solar nebula which, if it could now be viewed from a sufficiently great distance, would present much of its primitive appearance—the "zodiacal light" being, probably, a *palimprest* of a portion of the primitive nebulous mass whence the solar system as it is now known, has been derived.

SEVERINUS J. CORRIGAN.

St. Paul, Minnesota.
March 14, 1908.

How an Objective May Lose Figure. We were much interested in one paragraph found in a paper on the photometric observations by Joel Stebbins director of the observatory at the University of Illinois. The paragraph is as follows:—

"When the writer took charge of this Observatory in 1903, he found that the 12-inch objective had not given satisfaction for some years. The out of focus images were elliptical, and with good seeing the definition was rather poor. However, the lens was far from useless, and it seemed best to go ahead with the program of double stars, most of which were easy objects for an instrument of this size. During the summer of 1905, the writer was to be absent from the Observatory, and the lens was shipped to Allegheny at the request of Mr. Brashear, who naturally become interested when he learned that an objective of his manufactnre was not giving satisfaction. He found that the metal ring which holds the lenses in the cell had been pressed down on one side, and allowed to remain, causing a permanent bending principally of the flint lens. Although he was in no way responsible for this occurrence. Mr. Brashear kindly refigured both lenses without cost to the Observatory, and the objective was returned in October 1905. The defects were corrected, and we now have a first class objective."

Photometric Observations of Double Stars by Joel Stebbins.

A recent publication by Joel Stebbins Director of the Observatory at the University of Illinois is at hand. The publication is an important one, in that it considers not only angle and distance of the components of a double star, but also their magnitudes as well. It is a well-known fact that the weak point in the work of double star observations by the old micrometric methods is in relation to the magnitudes of the components which is always estimated by the observer. If he is experienced such estimates will probably be quite nearly true; but if he is not a skillful observer, the estimated results will be uncertain.

This part of the work by former methods has not been considered very important, for the aim was the study of the motion of the components, rather than their physical condition in regard to brightness. It is certainly important to have this feature added in the study of the double stars in the future when it can be done.

Dr. Stebbins has used, in this work, a 12-inch refractor by Brashear, mounting by Warner and Swasey, which was erected in 1906. He finds the driving clock runs well, giving star images nearly stationary except for a vibration of about 8″, periodic in four minutes, which is due to the eccentricity of the driving worm.

He uses a polarizing photometer by Alvan Clark and Sons, in the form devised by Professor Pickering, and described in Vol II. p. 4 of the *Annals* of Harvard College Observatory, designated photometer H. A. Wollaston, prism forms two images of each star, and these images are varied in intensity by rotating a Nicol prism between the eye and the eyepiece. When the stars are close together the ordinary image of one can be brought adjacent to the extraordinary image of the other, and the difference of magnitude is easily derived from the positions of the Nicol which produce equality in the two images compared."

Other interesting details of the method of work, and the results already obtained are given in this paper which will be of service to any who may wish to know more about it.

This publication contains a list of 107 double stars whose measures are catalogued on this plan. It is the intention of the director to continue this work, for he says there is enough work within the range of his instrument to keep an observer busy for his entire life.

Present Surface Temperatures of Mars, Venus and Mercury. The smaller planets Mars, Venus and Mercury, when viewed in contradistinction to the four great outer planets Jupiter, Saturn, Uranus and Neptune, may be regarded as quite similar to, and comparable with, the Earth, in respect to *mass*, dimensions and—in a certain sense—physical conditions, so that the absolute temperature of the surface of each, *relative* to the known, uniformly distributed and constant, temperature of the superficial matter of our globe at a depth of about 100 feet below its solid surface, which temperature is known to be, approximately, 52° Fahrenheit, or 512° of the *absolute* scale may be, in each case, taken as the *ratio* between the maximum internal temperature of the planet, and that in the case of the Earth, all of which absolute temperatures are set forth in Table IIa, on page 150 of the March number (153) of P. A., that of the Earth being, 6,800°; of Mars, 5,640°, of Venus 7,120° and of Mercury, 7,934°.

Therefore, the surface temperatures are: for Mars $\frac{5640°}{6800°} \times 512° = 424°$; or $-36°$ Fahrenheit; for Venus $\frac{7120°}{6800°} \times 512° = 536°$; or $+76°$ Fahrenheit, and for Mercury $\frac{7934°}{6800°} \times 512° = 597°$; or 137° Fahrenheit. Since any uncertainty in the value of the maximum internal temperature of the Earth attaches, in equal measure, to the case of each of the three other planets the *ratio* aforesaid is, obviously, unaffected, so that the value of the intrinsic temperature at a small depth below the solid surface, may be regarded as sufficiently well determined.

These are the temperatures due to the internal planetary heat alone, the augmentation caused by thermal radiation from the Sun being an independent quantity the maximum value whereof may be taken at about 70° F for the Earth, which would give, as the greatest temperature on the surface exposed to direct solar heat, the maximum intrinsic temperature 52° + the solar augmentation 70°, or 122° F, which is about the greatest temperature (in the shade) recorded in the hottest regions of our globe. The augmentation in the case of each of the other three planets is, obviously, inversely proportional to the square of its *relative* distance from the Sun, so that for Mars the value to be added to the intrinsic temperature (— 36°) aforesaid is + 76° F, making the actual surface temperature 0° Fahrenheit, from which determination it may be inferred that the climate of Mars, at best, is one of Arctic severity or that of an elevated plateau at an altitude of four, or five miles above sea-level, with respect to temperature compared with terrestrial conditions in this regard, and that the types of life thereon (if any there be) must correspond to those existing upon the Earth in similar situations. At the same time, the nature of the surface matter of Mars may be such that it may have a somewhat higher maximum temperature, particularly in the polar regions where it is exposed (during a period of insolation about twice as long as in the case of the Earth) to the direct solar rays, so that the temperature may at times, rise somewhat above the freezing-point as seems to be indicated by the behavior of the polar snow-cap.

The augmentation to be added to the intrinsic-temperature of the planet Venus (76°) is 114°, making a maximum surface temperature of 190° F which is not far below that of boiling water—a fact that accounts well for the dense clouds which seem to envelop that planet and reflect the incident sunlight so well that Venus is at times, the most brilliant object in the heavens

except the Sun. This temperature corresponds to that which, according to a determination of my theory, prevailed upon the Earth during the latter part of the Huronian-Cambrian Age of geological history, when the primitive forms of life first appeared upon the Earth, as evidenced by the molluscan fossils, the *trilobites*, the noted Eozoon Canadense etc., in the animal kingdom, and by the casts of the vegetable, "fucoids" all well suited to their environment in the warm, shallow waters of that remote age, between 50 and 60 millions of years ago, according to my determination as set forth in the III Part of my work treating of the "genesis of the solar system". In the case of the planet Mercury the augmentation due to solar heat is 393°, and this, added to the intrinsic temperature, gives 530° F as the maximum surface temperature on Mercury,—which is not much below that of the melting-point of lead—a fact that precludes the possibility of the existence of any known form of life on that planet. All of the above results are quite consistent with the best known facts.

SEVERINUS J. CORRIGAN.

St. Paul, Minnesota.

The Orbits and "Velocity-Curves" of Spectroscopic Binaries.*

In looking over the published papers on spectroscopic binaries, it will be remarked that the "velocity-curves"—as hitherto drawn for these objects—are often unsymmetrical. A closer examination reveals a curious *general similarity* in the form of such curves; the *ascending* branch of the curve, with few exceptions, being of greater length than the *descending* branch. This fact, although of great theoretical interest, seems to have been hitherto overlooked by astronomers. Its significance will be seen when we try to interpret it in accordance with received ideas. The result may be stated as follows:

Let D denote the time-interval during which the star's "radial velocity" is *decreasing*; I the interval during which it is *increasing* (algebraically); ω the longitude of periastron, reckoned from the ascending node. On the hypothesis of elliptic motion we have:

$$D < I \text{ if } \omega \text{ is between } 0° \text{ and } 180°,$$
$$D > I \text{ if } \omega \text{ is between } 180° \text{ and } 360°.$$

Now for the list of thirty spectroscopic binaries given in the paper, we find:

$$D = I \text{ for 1 star,}$$
$$D > I \text{ for 4 stars,}$$
$$D < I \text{ for 25 stars.}\dagger$$

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*Abstract of a paper communicated to the Royal Astronomical Society of Canada, revised and amended by the author March 11, 1908.

† Excluding these stars for which e is equal to or less than 0.10, we have:

$$D = I \text{ for 1 star,}$$
$$D > I \text{ for 2 stars,}$$
$$D < I \text{ for 21 stars.}$$

It should be added that the list of 30 binaries—with one notable exception—includes only stars for which the oscillation curve appears to be certainly unsymmetrical.

Thus in a large proportion of cases, the periastron is located (apparently) in the first or second quadrant of the orbit. A yet more remarkable feature is the apparent *grouping* of the periastra about certain values of ω. That such a distribution of the apses really exists is of course very improbable—so improbable that we are certainly justified in seeking for a different explanation of the observed facts. In other words, the elliptic elements e and ω, as computed for the orbits in question, are probably illusory; the "observed radial velocities," upon which they are based, being vitiated by some neglected source of systematic error.

After a careful study of the problem involved, the writer has been led to formulate a definite theory on the subject as outlined below. Without underestimating the difficulties of the problem, or denying the possibility that some other (and perhaps more probable) solution may yet be found, it is believed that the explanation here given rests upon a snbstantial basis:

(1) The disks of the stars under notice are not uniformly bright. The distribution of surface brightness in *longitude* is, for each star, unequal, and for some stars, distinctly unsymmetrical. Such conditions, combined with rapid axial rotation, would result in an unsymmetrical broadening of the spectral lines. The *effective* result would be a periodic shift of these lines, as measured on the spectrograms.

(2) The orbits of such binaries (especially those of short period) are, in general, nearly circular.

(3) The measured "radial velocity" is the resultant of orbital motion and axial rotation—as indicated above.

(4) Tidal action, as modified by friction and the general circulation of the stellar material, will probably account fully for the conditions postulated in (1). One very interesting and important consequence of this theory should be stated here, viz., that many (perhaps all) spectroscopic binaries are variable in brightness; though the range of their periodic light-changes must, in general, be small. Accurate photometric observations of such objects should, therefore, afford a crucial test of our hypothesis.

It would appear that both the light- and "velocity"-curves of the δ Cephei variables may be explained in conformity with these views. Confirmatory evidence is afforded by other facts of observation—e.g., the asymmetry in the light-curves of certain Algol stars—notably S Cancri, U Coronæ, and δ Librae.

For stars of the δ Cephei type, we must assume that the distribution of surface brightness is distinctly unsymmetrical. In ordinary cases, however, such an assumption is unnecessary.* The usual form of the "velocity-curve" (as indicated by the relation $D < I$) admits of a very simple and direct explanation. It is only necessary to suppose that the star's surface brightness at any point depends upon the *height of the tide* (due to a revolving satellite) at that point: *high* tide corresponding to *minimum* and *low* tide to *maximum* brightness. The orbit is regarded as circular (or nearly so), and the star is assumed to *rotate* in the same general direction as it *revolves*—an assumption that is both natural and theoretically probable. It should be added that the influence of tidal friction—where the periods of axial and orbital motion are unequal—may modify, in an important degree, the resulting form of the oscillation-curve.

* The degree of asymmetry (where such exists) must depend largely upon the *relative* distance of the tide-raising body.

In a future paper I hope to deal with various details of the theory outlined above and to discuss some practical methods for the separation of effects due, respectively, to axial rotation and orbital revolution of the stars under notice.

J. MILLER BARR.

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Canada.

Observatory of the Rev. J. H. Metcalf. In the sixty-second annual report E. C. Pickering the Director of the Astronomical Observatory of Harvard College, the following paragraph appears on page 8.

"It is the policy of the Harvard Observatory to aid, when possible, specialists who display marked skill in any department of astronomy. Coöperation has accordingly been established with the Observatory of the Rev. J. H. Metcalf so that the work there has been materially extended. This secures for the Harvard Observatory the immediate use of many excellent photographs and the eventual possession of certain valuable instruments. During the past year, Mr. Metcalf and his assistant have taken 200 photographs with a 12-inch doublet constructed by him. The greater portion of these plates were made by following upon a star, and giving an additional motion to the plate equal to that of an asteroid.

This method proves extremely effective in discovering and following asteroids and has led to the discovery of 33 asteroids, and of comet 1907 b, by Mr. Metcalf. The planet Eros also was found readily on July 4, 1907, on the first photograph taken for this purpose."

Mr. Metcalf is desirous that the orbits of these asteroids be computed so that a record of them may be made. He urges that observatories, colleges or individuals able to do the work and willing to make such a contribution to science will signify to him their desire to undertake the care of one or more of these planets.

The remarkable success of this new plan for photographic observation of faint comets and faint asteroids is claiming the attention of astronomers generally. It will be used more and more as time goes on.

Standard Tests of Photographic Plates by Edward S. King was published by Harvard College Observatory, as volume lix, No. 1, of its *Annals*.

Mr. King's discussion of the subject is full and detailed, the principal results attained in his investigation being summarized without respect to order of importance are given below.

1. The accuracy with which measures can be made with a photographic wedge, when it is under standard conditions. This is shown by the results in Table III, by the small residuals in Table IV, and by the almost exact duplication of the measures given in Table VI. It is shown also by the determination of the slight play of the scale, mentioned on page 5, amounting to only 0.03 magnitudes.

2. The difficulty of obtaining absolute results from photographic measures. This is shown by the diversity of results, when the experiments were made under almost exactly the same conditions.

3. The advantage of a system, in which the effect of the several elements contributing to the result have been studied from the same collection of plates.

4. The derivation of the nature of the error arising from the density of the film. The original plan did not provide for such an error, nevertheless

the material was sufficient to determine it.

5. That a little fogging of the plate is beneficial to the sensitiveness, but beyond a small amount becomes detrimental.

6. The care necessary to protect the sensitive film from all influences that may act like light, or affect the sensitiveness.

7. The necessity of repeating experiments sufficiently to eliminate the effect of such extraneous influences.

8. The slight differences found in the sensitiveness of the plates fresh from the maker and those three months old, or of plates developed immediately, and those developed three months after exposure.

9. The gain in the sensitiveness of the plates in use, amounting to 0.41 magnitudes, or almost 50 per cent, for the period discussed.

This paper is a suggestive one. It considers the features of the photographic plate that practical men want to know. The impression that we get in examining it, is that its results are preliminary in character, but doubtless point in the right direction. It would certainly interest those who deal much in astronomical photography to see this important investigation carried on still further.

Differential Equations by Cohen. This new book of 271 pages by Abraham Cohen, Associate in Mathematics at Johns Hopkins University, on Differential Equations is an elementary treatise and is published by Messrs. D. C. Heath and Co., Boston and Chicago.

The book is the result of the author's work in classes for some years as an instructor and it therefore takes the practical form that a teacher of large experience can give it. It can be pursued with advantage, by a student who has had a year's study in the calculus and such a student will find the course a splendid drill for him if he contemplates advanced studies in engineering, physical science, mathematical physics or the study of the higher pure mathematics including applications to practical astronomy.

We are interested to notice that the author plans to issue another book probably of advanced character, that will give the student knowledge of the wider range of Differential Equations showing more fully the splendid field that this branch opens to one prepared to go into it.

For an introductory work the one now in hand will commend itself highly for the purpose to those able to judge of it, or prepared to use it for study.

Differential and Integral Calculus by Osborn. Integral Calculus by Professor George A. Osborn of the Massachusetts Institute of Technology is a text that will interest any teacher of this branch who wants a text well planned and thoroughly up to date. The development of the various themes commonly pursued in first rate engineering schools, will be found in this text in a little different order from that pursued in some prominent engineering schools. In our judgment the author's arrangement is excellent. We have pursued the Sheffield School plan in preparing students in this branch of study either for engineering or for practical astronomy. In these two respects the Granville text has met our expectations well. It needs two full years of close study 16 hours per week to prepare the student thoroughly in both the Integral and the Differential for either of these two scientific lines of work. In that time he can master the principles and have practice enough in solving the given problems to test his knowledge and to exercise his powers of application in a breadth of training that ought to insure exceptional ability in

practical research. Anything less will fall short of a standard of scholarly value that ought to be rigorously maintained.

Professor Osborn's book is strongly recommended to teachers and students of mathematics.

The publishers are Messrs. D. C. Heath & Co., of Boston and Chicago.

A Course in Mathematics by Woods and Bailey. Volume 1, of A Course in Mathematics by Frederick S. Woods and Frederick H. Bailey, Professors of Mathematics in the Massachusetts Institute of Technology, recently published by Messrs. Ginn and Company, Boston, New York, Chicago and London, is before us.

These well-known authors of text-books in mathematics have devised a new plan for the study of the branches that have very generally gone under the names of Algebra, Analytic Geometry, Differential and Integral Calculus and Differential Equations. They have aimed to select from these various branches the essentials of each and relate them into one consecutive whole that would make two volumes for an entire course of mathematics for the work of students for two years in the engineering school. The first volume covers algebraic equations, functions of one variable, analytic geometry and the differential calculus.

It consists of 364 pages. To do this work the student is supposed to have finished trigonometry in the secondary school.

The first hundred pages of volume one in this new course deals with algebra beginning with elimination by determinants and ending with quadratics. A full discussion of roots is included and illustrations by the graphical method are freely used. The study of the algebraic function in general requires a knowledge of analytic geometry and the calculus and these principles must be understood before the student can advance even to simple applications. We also notice that it is necessary to use simple integration in some cases to carry out this new plan.

The subjects for study and the order of them, in the main, are logical and excellent, but the fear that arises in our mind is that too much is expected of the student in the way of preparation, on the one hand, and in ability on the other, to do the work expected of him in the time specified. There is not enough exercise in knowledge of principle and its applications to give the student the independence in thinking and doing for himself before leaving one theme to go to another more or less remotely connected with it.

If the student were expected to stop with the algebraic function and a few of the elementary transcendental functions, he might work the new plan successfully. But the authors think it is better to give less of the properties of these functions and more of the transcendental curves, which, it seems to us, is not the best way to study the generalizations of mathematics at this stage of the student's progress.

Also, we fear the plan requires the student to go over too much ground in the time given to it. This is the serious mistake that most recent authors are making. It is absolutely impossible for the good average student to do the work as it ought to be done in the time usually given for it. The effect of this is never satisfactory to student or teacher. It gives the wrong impression to the inexperienced instructor about what he ought to do in a given time, and leads him to crowd the student to the limit of his ability and often beyond it to do what is expected of him, and because he fails or succeeds very indifferently, he is discouraged and leaves the study of mathematics for something easier.

We have so often seen such results as these that we can not forbear speaking of them when so good a book as the one in hand is, in many respects, yet has this danger in its way that we have briefly and too hurriedly pointed out.

For years we have thought along this line and often spoken of it as conviction has grown upon us. Fully ten years ago while talking with Professor Simon Newcomb of Washington, D. C., in regard to this matter of teaching the calculus, he made this same point in clear and definite way. We thought then he was right and we are sure of it now.

Catalogue of Bright Clusters and Nebulae. The foregoing is the title of a paper by Solon I. Bailey which appeared as No. VIII of Volume LX of the *Annals* of Harvard College Observatory.

Mr. Bailey gives the following provisional classification of nebulae and clusters.

A. Vast, faint, irregular nebulosities, shown on photographs of long exposure. Examples; Nebula in Cygnus, Great Spiral about Orion.

B. Gaseous Nebulae. Objects having Gaseous Spectra.
   - B1. Large, diffused, irregular. Examples; Orion Nebula, ηCarinae Nebula.
   - B2. Planetary, ring, and other small, well-defined gaseous nebulae. Examples; N.G.C. 3587 (planetary), N.G.C. 6720 (ring), N.G.C. 6618.
   - B3. Nebulous stars. Examples; N.G.C. 1514, N.G.C. 2003.

C. White Nebula and Globular Clusters. Objects having continuous Spectra.
   - C1. Nebulae, small, unresolved, of somewhat definite form, generally round or elliptical. This group probably includes the great majority of small nebulae, many thousands in number.
   - C2. Spiral Nebulae. Examples; N. G. C. 224 (The Great Nebula in Andromeda) N.G C. 5194 (Spiral in Canes Venatici).
   - C3. Globular Clusters. Examples: N.G.C. 5139 (ω Centauri), N. G. C. 104 (47 Tucanae), N.G.C. 6205 (Great Cluster in Hercules).

D. Irregular Clusters.
   - D1. Fairly condensed, somewhat regular, stars of comparatively uniform magnitudes. Examples; N.G.C. 2437, N.G.C. 6494.
   - D2. Fairly condensed, irregular, stars of different magnitudes. Examples; N.G.C. 869 and 884 (Double Cluster in Perseus), N.G.C. 4755 (κ Crucis).
   - D3. Coarse, irregular, stars of different magnitudes. Examples; Hyades, Pleiades.

This catalogue of bright stars and clusters is an extremely interesting one, not only in its detailed descriptions, but especially also in the many fine reproductions from photographic plates. Plates 4 and 5 that bring out the nebulous regions about the Milky Way in the vicinity of Sagittarius and Scorpio and that surrounding η Carinæ are surprisingly clear, clean and full of interesting detail when examined under magnifying power. The original negatives must have been very good, the half-tones first rate and the printing almost faultless. We have had some experience in this kind of work and we know what it means and what it costs to be successful in doing such work well. We think Mr. Bailey's work in this paper is admirable.

Errata. In the March number, page 164, first line of second paragraph for "σ Hydra" read δ Hydra, and in next paragraph on same page, tenth line for "2° 15′ declination" read 1° 45′ S. Declination, twelfth line for "2° 45′" read 2° 15′, and in next line for "39° 41′" read 39° and 41°, and in last line of some paragraph for "43° 45′" read 43° 15′. Scale of Plate III should read 1mm = 41″.

The title from the table of contents of Mr. W. H. Pickering's article on Drawing Ellipses was unfortunately omitted.